Chester Creek Fish Passage Channel 35-% Design

(June 8, 2003 revision)

Project Background

The Alaska Railroad crosses the Chester Creek estuary on an earthen embankment and trestle that was constructed in 1934. In 1970-71, a dam was constructed along Chester Creek approximately 150-feet upstream of the railroad embankment to create Westchester Lagoon, a year-round recreational resource for the Municipality of Anchorage. Presently, flows from Westchester Lagoon are discharged over a weir and through two pipes discharging directly into the Knik Arm of the Cook Inlet. The pipes were placed through the railroad embankment in 1972 replacing the trestle. A number of buried utilities, including force sewer mains and petroleum pipelines, are buried in the downstream side of the railroad embankment (HDR, 2000).

The present lagoon outlet structure and pipes present a significant impediment to upstream and downstream fish passage. The lagoon structure also limits opportunities for fish to reside in the mixing zone between fresh and saline waters during upstream and downstream migrations.

Scope

Inter-Fluve, Inc. (Inter-Fluve) was retained as a sub consultant to HDR Alaska, Inc. (HDR) to develop 35-percent level design and plans for a fish passage stream channel extending from Westchester Lagoon through the railroad embankment and discharging into the Knik Arm of Cook Inlet. A preliminary channel design and plan had been prepared by HDR as part of a feasibility study (HDR, 2000). Site constraints for the new channel include the location and stability requirements of the existing Westchester dam and railroad embankment, and drop of nearly 21.3-ft across an intertidal area. As shown on the attached 35-percent level plans, elements of the proposed fish passage channel project include:

- An open channel to convey the majority of Chester Creek flows (the remaining flows pass through the existing weir structure). To the extent possible within project site constraints, channel morphology mimics conditions found within natural streams to provide improved upstream and downstream fish passage, fresh/saline water mixing zones and aesthetic values.
- Pool and riffle habitats for improved fish passage conditions. These features also increase the fresh and saline water mixing area throughout the intertidal zone.
- Woody debris placed within the existing pond to provide cover habitat for both returning adult and resident juvenile fish.
- Constructed vegetated berms to direct flow pathways of larger flood flows in order to prevent channel avulsion across the existing grassy marshland area. The berms are limited in area to minimize the volume and encroachment area of fill placed in the intertidal area.

- Channel stability was designed to minimize the need for continued operation and maintenance of the project.
- A streambed constructed of subangular to rounded river rock to provide habitat, channel planform stability and aesthetic values.
- To provide the desired level of stability for the lagoon dam and railroad embankment, the channel boundaries are stabilized with riprap up to the level of the 100-year flood. In addition, riprap was extended to the top of the bank along side slopes steeper than 3H:1V to provide bank mass stability.
- Size of rounded rock and riprap was designed to provide channel stability for flows during low tide conditions. Rock placements between Stations 10+00 and 23+00 were designed to be stable for flows up to the 100-year event. Riprap placements between Stations 23+00 and the 25+50 were designed to be stable for flows up to the 500-year event. Design rock size was compared to existing revetments along adjacent streams that have withstood multiple seasons of ice forces.

Field Visit

Inter-Fluve visited the site with HDR on August 22, 2001. The proposed project was discussed and viewed in the field with HDR. The location of the historic Chester Creek estuary along the Knik Arm side of the railroad embankment was viewed. The adjacent estuary of Fish Creek was viewed during an outgoing high tide. Digital photographs were taken of these areas.

Channel Reaches

The new channel will connect Chester Creek between Westchester Lagoon and the Knik Arm. The new channel will drop about 21.3-ft, traversing an intertidal zone over the majority of its length. There is an existing pond along the south side of the project footprint. The channel was developed to optimize habitat value of the existing pond. As shown on Sheets 1 and 2, the proposed channel will be comprised of three reaches:

- Reach 1 (Station 10+00 to 12+35) – this 235-ft reach of channel extends from a new weir outlet from Westchester Lagoon and will discharge into the existing pond.
- Reach 2 (Station 12+35 to 16+20) - this 385-ft long reach is a deepened section through the existing pond to create a meandering channel. The overall pond footprint will not be changed and water levels similar to existing conditions will be maintained.
- Reach 3 (Station 16+20 to 25+53) - this 933-ft long reach of channel discharges from the existing pond, passes through a proposed trestle through the railroad embankment and discharges into Knik Arm at the historic location of Chester Creek. This reach of stream is subject to tidal fluctuations.

Channel Plan Form

The proposed location of the channel was governed by the locations of the existing Westchester Lagoon dam and the railroad embankment. Both of these structures provide important functions that need to be preserved and their stability is to be maintained. Within the constraints imposed by the dam, railroad embankment and utilities, the channel plan form was located to provide the greatest channel length and morphologic diversity to provide fish passage and mixing zones for fresh and saline water. Resting areas are provided by pools separated by riffles that are approximately 50 to 60 feet in length. For the stated project goals, the channel cannot provide full natural geomorphic function as migration or erosion could contribute to destabilization of the adjacent structures.

For the available channel length the elevations range from 16.0-ft at the new outlet weir invert, 12.7-ft at the existing pond to –5.5-ft at the transition to the historic Chester Creek channel in the Knik Arm. Thus, the resulting channel morphology of Reaches 1 and 3 are more representative of higher gradient (2.4-percent) streams and has little in common with the historic low gradient Chester Creek estuarine channel and adjacent low gradient streams through fine soils (e.g. Fish Creek).

To provide morphologic function and aesthetic values within the constructed nature of the new channel, the proposed plan form is based on geomorphic regime equations. Regime equations provide estimates for ranges of values of meander length, width and radii typical of natural channels based on a channel forming flow approximately equal to 60-cfs. This plan form maximizes the associated pool/riffle sequences to maximize pool habitat for saline/fresh water mixing. Based on the 'no maintenance' project criteria, the proposed channel will be stabilized with rock in the constructed configuration. Thus, the purpose of the geomorphic regime analysis is to provide guidelines for a channel plan form with a natural appearance.

Reach 2 is located within the existing pond and is intended to have a meandering plan form characteristic of a low gradient channel backwatered by beaver activity. The following discussions will focus on Reaches 1 and 3.

Channel Design Hydrology

An analysis of Chester Creek hydrology for return period event peak flows was prepared by HDR and discussed in Section 1.1, Chester Creek Hydrology. Flows are distributed between two flow paths: 1) the new weir and channel and 2) the existing concrete weir. The flow distributions for various total flows along Chester Creek are summarized in Section 1.1.

Values of average daily discharges along Chester Creek were obtained from the USGS gauge no. 15275100 entitled *Chester Creek at Arctic Boulevard at Anchorage, Alaska.* Average daily discharge values were available for a period of record June 17, 1966 to March 11, 1986; June 1, 1987 to September 30, 1993; and October 1, 1998 to September

30, 2000. The average daily discharges for all years during the period of record were plotted by calendar year and shown in Figure 1.

Upstream migration of Coho, Pink, Chum, Chinook and Sockeye Salmon were assumed to occur primarily during the May through mid September time frame (ADF&G sport fish run timing web page). Downstream migration was assumed to occur primarily during the April through end of June time frame (Bell, 1991). The values of average daily discharges along Chester Creek occurring during months of expected fish upstream and downstream migrations are shown on Figure 1.

Chester Creek flows, during upstream and downstream fish migrations, range from a low of 10-cfs to a high of 75-cfs, with the majority of flows occurring at 50-cfs or less. The 75-cfs flow has been exceeded less than 1-percent of the time over the period of record. Channel hydraulic conditions were estimated for fish passage flows of 10-cfs, 50-cfs and 75-cfs.

From correspondence with NRCS, a channel forming, or bank full, flow of approximately 60-cfs total Chester Creek flow was assumed (Sampson, February, 2002). Of this flow approximately 48-cfs passes over the new weir and along the new channel.

Hydraulics

Fish passage criteria for design of open channels were discussed with ADFG biologists who indicated that Alaska has no established criteria for passage along open channels and referred to culvert passage methods. From the computer model FishXing (version 2.2), the default minimum flow depth for adult Chinook Salmon is 0.8-ft; for adult Chum, Pink and Steelhead is 0.6-ft; no values are suggested for Coho or Sockeye. Thus, it was assumed that 0.8-ft would be a reasonable minimum depth for the minimum expected flows.

Hydraulic conditions along a typical riffle-pool-riffle sequence were modeled using the US Army Corps of Engineers one-dimensional HEC-RAS (version 3.0) open channel hydraulic model. For shallow flow depths during low flows with projection of the constructed rock bed into much of the flow profile, a Mannings roughness coefficient of 0.048 was assumed. A flow depth of 0.8-ft at 10-cfs along the new channel is provided. For deeper flows, a Mannings roughness coefficient of 0.043 was assumed. Model boundary conditions were assigned as normal depth based on the slope of the channel invert profile along the riffle. Low tide conditions were modeled to account for the greatest flow energy along the channel.

A method to estimate Manning's roughness based on contributing factors is presented in the publication by George J. Arcement, Jr. and Verne R. Schneider, 1989, Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains", USGS Water-Supply Paper 2339. Basic Manning's n for boulder bed streams is n = 0.040 to 0.070; for cobble bedded streams n = 0.030 to 0.050. The proposed design calls

for subrounded to rounded boulders with voids filled with a gravel, cobble mixture. Therefore, for this relatively 'smooth' material the lower end of the boulder range seemed appropriate. Additional roughness is contributed by irregularity (smooth, n = 0.000 to minor, n = 0.001), change in cross section (gradual, n = 0.000), obstructions (negligible, n = 0.000 to 0.004), vegetation (none, n = 0.000), and meandering (minor, n = 1.0). Additional description is provided in Arcement and Schneider on the quantitative criteria to estimate the degree of contributing roughness.

While the Mannings "n" of the final constructed channel may be greater than that assumed at this level of design, it is our experience that using a more conservative "n" ensures the final constructed channel meets the fisheries design goals. Using the lower "n" of 0.048 means that to meet the minimum death requirements for fish passage at the lowest flows the channel will have to be narrower. Often contractors construct smoother channels than anticipated. If the final constructed channel is rougher, a larger "n" value, the water will flow deeper and fish passage will be enhanced. High flow capacity is maintained through the use of a larger high flow channel.

The channel cross-sectional geometry was developed iteratively to provide 0.8-ft of flow depth during the lowest expected flows. During the months of migration, the lowest flows recorded at the gauge over the period of record are about 10-cfs. Typical stream flow values of 50- and 75-cfs have an associated flow depths ranging between 1.1-ft and 1.5-ft. Ranges of channel velocities of approximately 5.4- to 6.2-fps were estimated for the 50- and 75-cfs flows.

The entire project reach from Station 10+00 to Station 25+50 was also modeled with HEC-RAS version 3.0. For the deeper flow depths, a Mannings roughness coefficient of 0.043 was assumed. Both high and low tide boundary conditions were modeled. Occurrences of supercritical flow prevented the use of the option for unsteady boundary conditions as the model failed to execute. Cross sections were located at the upstream and downstream ends of riffles and at pool centers. The HEC-RAS option to interpolate cross section geometry was used. Flows distributed between the new and existing weirs converge at approximately Station 23+20.

Hydraulic forces along the channel were estimated for flows up to and including the 500-year event. From Station 10+00 through 12+35 and 16+20 through 21+50, flood terraces totaling 20-ft in width are included which inundate during flows greater than the bank full flow of 60-cfs total Chester Creek flow. The greatest shear force equal to 3.4-psf along the channel bed occurs during the 100-year event. The 100-year flow depth is approximately 2.7-ft. The 100-year flow velocity is approximately 8.0-fps.

Downstream of Station 22+70 the site is tightly constrained by the dam and railroad embankment and the channel is limited to no flood terrace and side slopes at 2H:1V for the entire depth from channel bed up to the existing ground. There is no impact to hydraulics of fish passage flows through this constrained channel. Riprap along this subreach was designed to a 500-year event to meet dam-safety requirements. The 500-

year flow has a shear equal to 4.7-psf, flow depth equal to 3.4-ft and velocity equal to 11.5-fps.

The channel invert was set at elevation 12.7-ft at the outlet of the pond. This elevation was selected so that the normal flow depth along the outlet channel at 10-cfs would match the existing pond water level. This is necessary to maintain pond water levels similar to existing conditions.

Sediment/ Channel Stability

The new channel is located immediately downstream of Westchester Lagoon. The Lagoon is an effective sediment trap, preventing any conveyance of naturally occurring fluvial sediment. Based on the project requirement for no ongoing operation or maintenance, the completed channel necessarily must provide immediate and long term stability against erosion by hydraulic forces, ice forces and other disturbances. The streambed substrate included in the proposed plan from Station 10+00 to 23+00 was sized to provide long term stability for flows up to and including the 100-year event at low tide. Downstream of Station 23+00 the design criterion is erosion protection for flows up to the 500-year event to meet dam-safety requirements. Riprap is proposed along the channel margins and along the bank at the downstream end of the new channel to provide a higher factor of safety for bank erosion protection for the dam and railroad embankment. The new channel immediately downstream of the weir will be armored to protect against the formation of any scour hole. The armor will be designed to withstand the weir flowing full, which is the lagoon full to the top of the dam or elevation 18.5 MSL.

Along the channel bed, a subangular to rounded stone is proposed to provide habitat and aesthetic values. Design of rock size using the moment stability method account for the rounded character of the rock by assigning a minimum Phi equal to 36 degrees (subangular rock has a phi equal to 39 degrees while angular rock has a phi equal 41 degrees). In addition, for substrate placed along the bed, the flow vector along the bed was assigned the maximum destabilizing orientation. Thus, the roundedness, rolling potential and reduction of interlocking characteristics are accounted for in the design to provide a stable bed substrate. Along the riffles, rock size was estimated to have a D84 equal to 15-inches for rounded rock placed along the bed and D84 equal to 33-inches for subangular rock placed along a 2H:1V stream bank. These sizes were verified using the ASCE, Isbash and USCOE rock sizing methods. The gradation of the substrate materials is shown on Sheet 11 of the plans. Use of smaller angular riprap material will function adequately from an erosion control standpoint but was assumed to have less habitat and aesthetic values than a rounded or subrounded stone. Pools are also lined with substrate materials. The outside bend along the pools are designed to be at a 1.5H:1V side slope. Some mobility of the stone along these steeper banks is likely to occur during the highest design flows. However, there is adequate thickness of rock to provide stability of the bed should movement create a 2H:1V side slope.

Along the outer margins of the new channel, riprap is proposed to provide erosion protection for the 100-year event from Station 10+00 to 23+00 and the 500-year event

downstream of Station 23+00. In addition the channel side slopes downstream of Station 22+70 will be steeper than slopes of existing stable fine-grained soil banks (about 3H:1V). Along these steeper constructed banks, riprap is proposed to provide protection to the dam and railroad embankment from bank sloughing or mass instability. An ADOT Class III riprap was selected using the ASCE, Isbash and USCOE rock sizing methods.

Design methods for sizing rock to resist ice forces is not well documented. The design rock size is similar to sizes in existing revetments along the Fish Creek bridge abutment that has experienced multiple seasons of ice forces. A number of existing revetments that had experienced a multiple winter seasons were examined by HDR and size and gradations noted. An ADOT Class III riprap gradation was observed to perform satisfactorily (HDR, April, 2002).

Geomorphically, quality gravels that have sufficient inter-gravel flow used for spawning are generally mobilized by flow every 2- to 5-years (thereby, removing embedded fine-grained materials). In addition, quality spawning gravels are readily moved by fish. Given the absence of a natural replenishment source for spawning sized gravels, gravels placed with the purpose of providing spawning habitat would be removed from the channel by fish action and hydraulic forces within a short time period. To meet the project objective of no ongoing operation or maintenance, a routine gravel replenishment operation was not considered. Therefore, spawning habitat is not included in this proposed plan.

Scour associated with flow along bends was calculated using equations from Maynord (1996) for typical riffle-pool morphology at bank full flows and the larger channel section for flows up to the 100-year event. Scour depths of 1.8- to 2.1-ft were estimated. These depths are consistent with the design pool depths of 1.8-ft below the residual pool water level. Additional scour potential is limited by the rock bed and banks designed to provide stability.

At the new inlet into the existing pond, the rock lined channel is extended into the pond to Station 12+35, as shown on Sheet 1. The formation of a scour hole at the end of the armored channel within the pond footprint was examined. Table 2-5 of the USCOE EM 1110-2-1601 (1994) indicates a permissible velocity before erosion occurs of 3.5-fps for silty-clay and 6.0-fps for clay soils. Flow velocities entering the pond are less than 6-fps. Therefore, the depth of the scour hole in the in-situ clay soils (Shannon & Wilson, 2001) is anticipated to be minimal and is not anticipated to impact adjacent structures. Formation of a scour hole will provide pool habitat.

Flow depths at the upstream end of the Reach 3 channel (Station 16+20) will control water levels in the pond. The flow depth of the 10-cfs minimum anticipated flow as it enters and is conveyed along the downstream channel is equal to the existing pond water level. Erosion protection from flows discharging from the pond will be controlled by the rock lined bed and banks of the Reach 3 channel. Riprap will be extended from the upstream end of the Reach 3 channel laterally along the berms for a distance of 15-feet to protect from erosion caused by acceleration of flows exiting the pond.

References:

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HDR Alaska Inc., April 25 2000 *Chester Creek Channel Design Field Memo.*

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Shannon & Wilson, Inc., July 2001, *Geotechnical Report Chester Creek Improvements Westchester Lagoon Fish Passage, Anchorage, Alaska.*

Six Rivers National Forest Watershed Interactions Team, 1999, "FishXing, Version 2.2"

Tullis, J. Paul, N. Amanian, and D. Waldron, *Design of Labyrinth Spillways*, "Journal of Hydraulic Engineering", ASCE Vol. 121, No. 3, March 1995, pp. 247-255

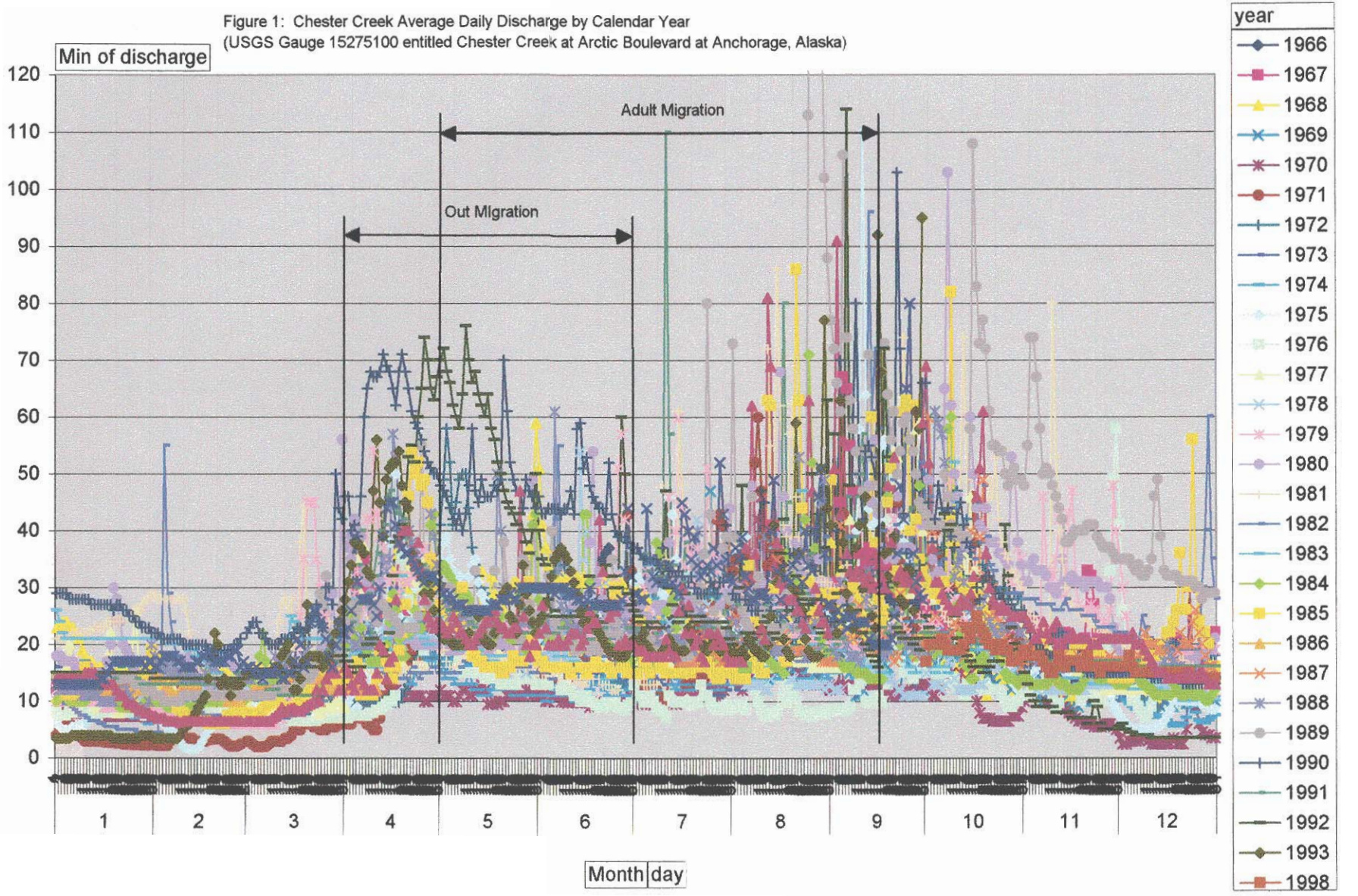
USCOE, EM 1110-2-1601, *Hydraulic Design of Flood Control Channels*, June 1994

USGS stream flow data (Gauge No. 15275100 "Chester Creek at Arctic Boulevard at Anchorage, Alaska").

WEST Consultants, Inc, USDA Forest Service, July 1997, *WinXSPro a Cross Section Analyzer.*

WEST Consultants, Inc, RIPRAP Design System, Version 2.0.

Figure 1: Chester Creek Average Daily Discharge by Calendar Year
(USGS Gauge 15275100 entitled Chester Creek at Arctic Boulevard at Anchorage, Alaska)



Appendix:

HEC-RAS

Geomorphic Plan Form Calculations

Rock Size Calculations

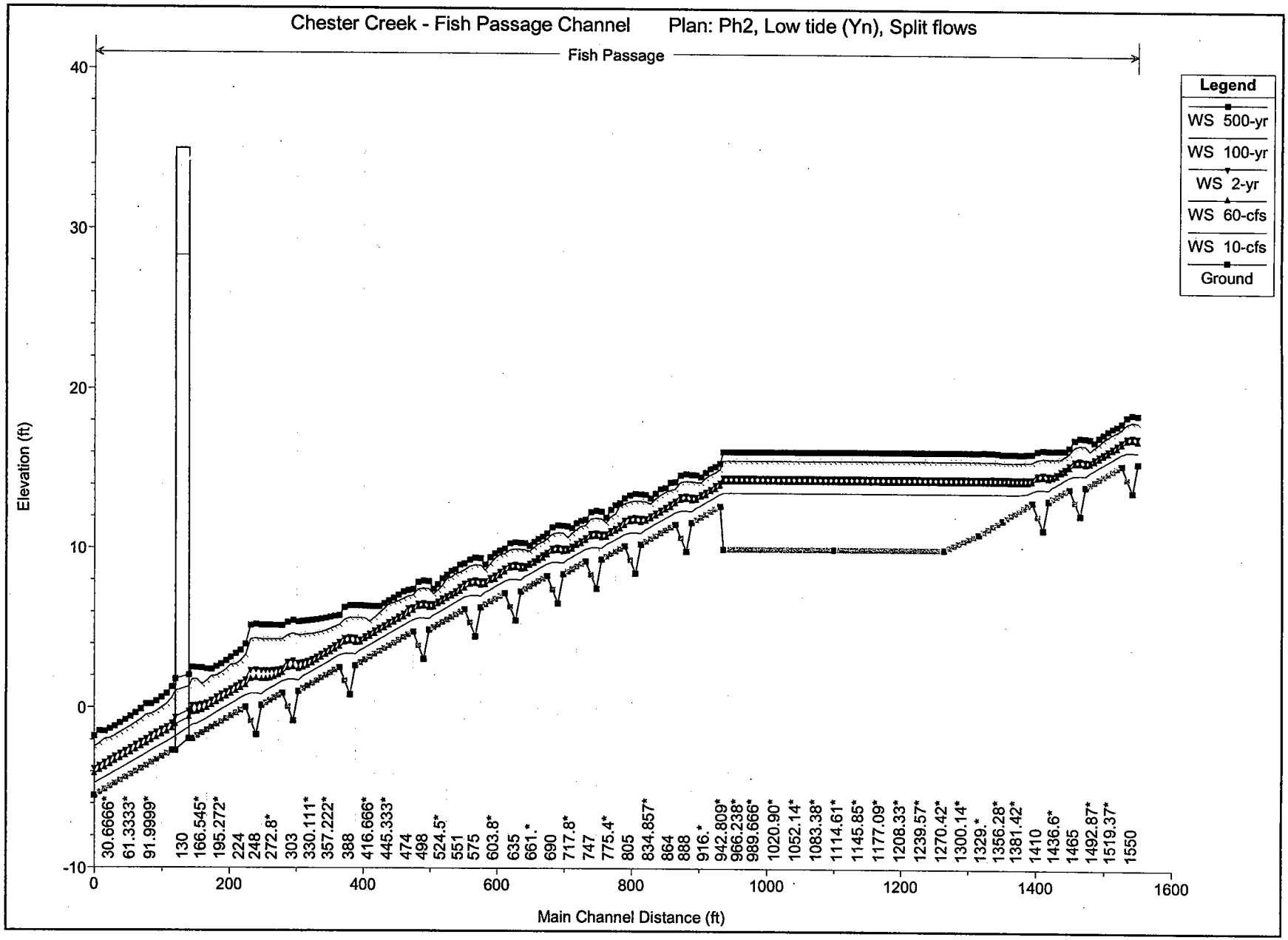
Bend Scour Calculations

Channel Centerline station - HEC-RAS Section Identifier

Centerline station begins upstream and increases
in the downstream direction
HEC-RAS calculation proceed from downstream to upstream
HEC-RAS Section Identifier defines location with modeled reach
For HEC-RAS model order of stationing was reversed

centerline station	HEC-RAS ID
1000	1550
1008	1542
1024	1526
1077	1473
1085	1465
1101	1449
1132	1418
1140	1410
1156	1394
1200	1350
1235	1315
1615	935
1620	930
1662	888
1670	880
1686	864
1737	813
1745	805
1761	789
1795	755
1803	747
1819	731
1852	698

centerline station	HEC-RAS ID
cont'd	
1860	690
1876	674
1915	635
1923	627
1939	611
1975	575
1983	567
1999	551
2052	498
2060	490
2076	474
2162	388
2170	380
2186	364
2247	303
2255	295
2271	279
2302	248
2310	240
2326	224
2405	145
2435	115
2550	0


Chester Creek - Fish Passage Channel
Plan: Ph2, Low tide (Yn), Split flows
Fish Passage
Legend
WS 500-yr
WS 100-yr
WS 2-yr
WS 60-cfs
WS 10-cfs
Ground
Elevation (ft)
Main Channel Distance (ft)
40
30
20
10
0
-10
0
200
400
600
800
1000
1200
1400
1600
30.6666*
61.3333*
91.9999*
130
166.545*
195.272*
224
248
272.8*
303
330.111*
357.222*
388
416.666*
445.333*
474
498
524.5*
551
575
603.8*
635
661.*
690
717.8*
747
775.4*
805
834.857*
864
888
916.*
942.809*
966.238*
989.666*
1020.90*
1052.14*
1083.38*
1114.61*
1145.85*
1177.09*
1208.33*
1239.57*
1270.42*
1300.14*
1329.*
1356.28*
1381.42*
1410
1436.6*
1465
1492.87*
1519.37*
1550

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	1550	10-cfs	10.00	15.50	16.19	16.19	16.32	0.042128	2.95	3.39	12.36	0.99
Fish Passage	1550	60-cfs	48.00	15.50	16.87	16.79	17.04	0.012849	3.50	15.96	35.06	0.66
Fish Passage	1550	2-yr	84.00	15.50	17.16	17.03	17.35	0.010296	3.81	26.59	36.25	0.62
Fish Passage	1550	100-yr	280.00	15.50	18.09	17.73	18.43	0.009301	5.33	61.71	39.94	0.65
Fish Passage	1550	500-yr	417.00	15.50	18.55	18.10	18.99	0.009182	6.05	80.56	41.79	0.67
Fish Passage	1542	10-cfs	10.00	13.68	16.24	14.41	16.24	0.000151	0.52	19.05	12.70	0.08
Fish Passage	1542	60-cfs	48.00	13.68	16.94		16.98	0.000923	1.57	34.74	35.54	0.20
Fish Passage	1542	2-yr	84.00	13.68	17.22		17.29	0.001572	2.23	44.69	36.64	0.26
Fish Passage	1542	100-yr	280.00	13.68	18.12		18.35	0.003742	4.30	79.30	40.24	0.43
Fish Passage	1542	500-yr	417.00	13.68	18.58		18.90	0.004519	5.17	98.17	42.07	0.48
Fish Passage	1526	10-cfs	10.00	15.38	16.12		16.21	0.025476	2.52	3.97	12.54	0.79
Fish Passage	1526	60-cfs	48.00	15.38	16.67	16.67	16.91	0.018823	4.00	13.43	34.77	0.79
Fish Passage	1526	2-yr	84.00	15.38	16.91	16.91	17.20	0.018087	4.65	21.70	35.71	0.80
Fish Passage	1526	100-yr	280.00	15.38	17.67		18.21	0.017674	6.63	49.97	38.75	0.87
Fish Passage	1526	500-yr	417.00	15.38	18.05		18.74	0.017595	7.52	65.07	40.28	0.90
Fish Passage	1473	10-cfs	10.00	14.03	14.72	14.72	14.85	0.042122	2.95	3.39	12.36	0.99
Fish Passage	1473	60-cfs	48.00	14.03	15.40	15.32	15.57	0.012834	3.50	15.97	35.06	0.66
Fish Passage	1473	2-yr	84.00	14.03	15.69	15.56	15.88	0.010314	3.81	26.57	36.25	0.62
Fish Passage	1473	100-yr	280.00	14.03	16.62	16.26	16.97	0.009190	5.30	61.91	39.96	0.65
Fish Passage	1473	500-yr	417.00	14.03	17.09		17.53	0.009023	6.01	80.93	41.82	0.66
Fish Passage	1465	10-cfs	10.00	12.21	14.77	12.94	14.77	0.000151	0.53	19.05	12.70	0.08
Fish Passage	1465	60-cfs	48.00	12.21	15.47		15.51	0.000923	1.57	34.75	35.54	0.20
Fish Passage	1465	2-yr	84.00	12.21	15.75		15.82	0.001574	2.24	44.68	36.64	0.26
Fish Passage	1465	100-yr	280.00	12.21	16.65		16.88	0.003718	4.29	79.48	40.26	0.42
Fish Passage	1465	500-yr	417.00	12.21	17.12		17.44	0.004470	5.15	98.54	42.11	0.48
Fish Passage	1449	10-cfs	10.00	13.91	14.64		14.74	0.025986	2.54	3.94	12.54	0.80
Fish Passage	1449	60-cfs	48.00	13.91	15.20	15.20	15.44	0.018823	4.00	13.43	34.77	0.79
Fish Passage	1449	2-yr	84.00	13.91	15.44	15.44	15.73	0.018087	4.65	21.70	35.71	0.80
Fish Passage	1449	100-yr	280.00	13.91	16.14	16.14	16.73	0.020181	6.94	47.83	38.53	0.93
Fish Passage	1449	500-yr	417.00	13.91	16.51	16.51	17.27	0.020211	7.88	62.16	39.99	0.96
Fish Passage	1418	10-cfs	10.00	13.13	13.82	13.82	13.95	0.042122	2.95	3.39	12.36	0.99
Fish Passage	1418	60-cfs	48.00	13.13	14.50	14.42	14.67	0.012831	3.50	15.97	35.06	0.66
Fish Passage	1418	2-yr	84.00	13.13	14.79	14.66	14.98	0.010557	3.84	26.36	36.23	0.63
Fish Passage	1418	100-yr	280.00	13.13	15.79		16.10	0.008138	5.09	64.52	40.22	0.61

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	1418	500-yr	417.00	13.13	16.30		16.69	0.007619	5.68	85.75	42.28	0.61
Fish Passage	1410	10-cfs	10.00	11.30	13.87	12.03	13.87	0.000149	0.52	19.18	12.74	0.07
Fish Passage	1410	60-cfs	48.00	11.30	14.58		14.61	0.000901	1.56	35.13	35.58	0.19
Fish Passage	1410	2-yr	84.00	11.30	14.85		14.92	0.001551	2.22	44.94	36.67	0.26
Fish Passage	1410	100-yr	280.00	11.30	15.82		16.03	0.003358	4.14	82.42	40.55	0.40
Fish Passage	1410	500-yr	417.00	11.30	16.33		16.62	0.003864	4.90	103.73	42.60	0.44
Fish Passage	1394	10-cfs	10.00	13.01	13.74	13.70	13.84	0.025768	2.53	3.95	12.54	0.79
Fish Passage	1394	60-cfs	48.00	13.01	14.30	14.30	14.54	0.018823	4.00	13.43	34.77	0.79
Fish Passage	1394	2-yr	84.00	13.01	14.54		14.83	0.017829	4.63	21.81	35.72	0.80
Fish Passage	1394	100-yr	280.00	13.01	15.57		15.93	0.009864	5.44	60.54	39.82	0.67
Fish Passage	1394	500-yr	417.00	13.01	16.10		16.53	0.008590	5.91	82.38	41.96	0.65
Fish Passage	1350	10-cfs	10.00	11.89	13.55		13.55	0.000150	0.46	26.34	36.23	0.07
Fish Passage	1350	60-cfs	48.00	11.89	14.26		14.27	0.000434	1.07	53.02	39.06	0.14
Fish Passage	1350	2-yr	84.00	11.89	14.54		14.57	0.000740	1.53	64.30	40.20	0.18
Fish Passage	1350	100-yr	280.00	11.89	15.54		15.65	0.001978	3.23	110.88	56.17	0.32
Fish Passage	1350	500-yr	417.00	11.89	16.07		16.22	0.002150	3.73	141.62	59.36	0.34
Fish Passage	1315	10-cfs	10.00	11.00	13.55		13.55	0.000001	0.05	227.32	148.37	0.01
Fish Passage	1315	60-cfs	48.00	11.00	14.26		14.26	0.000005	0.15	334.79	154.06	0.02
Fish Passage	1315	2-yr	84.00	11.00	14.55		14.55	0.000010	0.22	379.93	156.38	0.02
Fish Passage	1315	100-yr	280.00	11.00	15.59		15.60	0.000034	0.51	547.74	164.75	0.04
Fish Passage	1315	500-yr	417.00	11.00	16.15		16.15	0.000045	0.64	640.18	168.00	0.05
Fish Passage	1263	10-cfs	10.00	10.00	13.55		13.55	0.000000	0.06	233.90	148.37	0.01
Fish Passage	1263	60-cfs	48.00	10.00	14.26		14.26	0.000003	0.18	341.34	154.06	0.02
Fish Passage	1263	2-yr	84.00	10.00	14.55		14.55	0.000007	0.28	386.44	156.38	0.02
Fish Passage	1263	100-yr	280.00	10.00	15.59		15.60	0.000025	0.61	553.99	164.73	0.05
Fish Passage	1263	500-yr	417.00	10.00	16.14		16.15	0.000035	0.77	646.23	168.00	0.06
Fish Passage	1099	10-cfs	10.00	10.00	13.55		13.55	0.000000	0.06	233.89	148.37	0.01
Fish Passage	1099	60-cfs	48.00	10.00	14.26		14.26	0.000003	0.18	341.24	154.05	0.02
Fish Passage	1099	2-yr	84.00	10.00	14.55		14.55	0.000007	0.28	386.24	156.37	0.02
Fish Passage	1099	100-yr	280.00	10.00	15.59		15.59	0.000025	0.61	553.01	164.68	0.05
Fish Passage	1099	500-yr	417.00	10.00	16.13		16.14	0.000035	0.77	644.64	168.00	0.06
Fish Passage	935	10-cfs	10.00	10.00	13.55		13.55	0.000000	0.06	233.87	148.37	0.01
Fish Passage	935	60-cfs	48.00	10.00	14.26		14.26	0.000003	0.18	341.14	154.05	0.02

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	935	2-yr	84.00	10.00	14.55		14.55	0.000007	0.28	386.03	156.36	0.02
Fish Passage	935	100-yr	280.00	10.00	15.58		15.58	0.000025	0.61	552.04	164.63	0.05
Fish Passage	935	500-yr	417.00	10.00	16.13		16.13	0.000035	0.77	643.04	168.00	0.06
Fish Passage	930	10-cfs	10.00	12.70	13.44		13.54	0.023986	2.47	4.04	12.57	0.77
Fish Passage	930	60-cfs	48.00	12.70	13.99	13.99	14.23	0.018824	4.00	13.43	34.77	0.79
Fish Passage	930	2-yr	84.00	12.70	14.24		14.52	0.017423	4.59	22.00	35.74	0.79
Fish Passage	930	100-yr	280.00	12.70	15.02		15.53	0.016367	6.46	51.26	38.88	0.84
Fish Passage	930	500-yr	417.00	12.70	15.40		16.07	0.016607	7.38	66.32	40.40	0.87
Fish Passage	888	10-cfs	10.00	11.67	12.36	12.36	12.49	0.042122	2.95	3.39	12.36	0.99
Fish Passage	888	60-cfs	48.00	11.67	13.03	12.96	13.21	0.012999	3.51	15.88	35.05	0.66
Fish Passage	888	2-yr	84.00	11.67	13.33	13.20	13.52	0.010312	3.81	26.57	36.25	0.62
Fish Passage	888	100-yr	280.00	11.67	14.24		14.60	0.009515	5.37	61.20	39.89	0.66
Fish Passage	888	500-yr	417.00	11.67	14.70		15.15	0.009454	6.10	79.70	41.70	0.68
Fish Passage	880	10-cfs	10.00	9.85	12.41	10.58	12.41	0.000151	0.52	19.06	12.71	0.08
Fish Passage	880	60-cfs	48.00	9.85	13.11		13.15	0.000925	1.57	34.70	35.53	0.20
Fish Passage	880	2-yr	84.00	9.85	13.39		13.46	0.001582	2.24	44.57	36.63	0.26
Fish Passage	880	100-yr	280.00	9.85	14.28		14.51	0.003782	4.32	78.91	40.20	0.43
Fish Passage	880	500-yr	417.00	9.85	14.73		15.06	0.004589	5.20	97.47	42.01	0.48
Fish Passage	864	10-cfs	10.00	11.55	12.29		12.39	0.024913	2.50	4.00	12.55	0.78
Fish Passage	864	60-cfs	48.00	11.55	12.84	12.84	13.08	0.018823	4.00	13.43	34.77	0.79
Fish Passage	864	2-yr	84.00	11.55	13.08	13.08	13.37	0.018084	4.65	21.70	35.71	0.80
Fish Passage	864	100-yr	280.00	11.55	13.78	13.78	14.37	0.020160	6.93	47.82	38.52	0.93
Fish Passage	864	500-yr	417.00	11.55	14.23		14.91	0.017222	7.47	65.46	40.32	0.89
Fish Passage	813	10-cfs	10.00	10.29	10.98	10.98	11.11	0.042122	2.95	3.39	12.36	0.99
Fish Passage	813	60-cfs	48.00	10.29	11.65	11.58	11.83	0.013067	3.52	15.84	35.05	0.66
Fish Passage	813	2-yr	84.00	10.29	11.98	11.82	12.15	0.009328	3.68	27.53	36.36	0.59
Fish Passage	813	100-yr	280.00	10.29	13.00		13.30	0.007285	4.91	66.88	40.45	0.58
Fish Passage	813	500-yr	417.00	10.29	13.44		13.84	0.007836	5.73	84.89	42.20	0.62
Fish Passage	805	10-cfs	10.00	8.47	11.03	9.20	11.03	0.000151	0.52	19.06	12.70	0.08
Fish Passage	805	60-cfs	48.00	8.47	11.73		11.77	0.000927	1.57	34.68	35.53	0.20
Fish Passage	805	2-yr	84.00	8.47	12.03		12.09	0.001518	2.21	45.31	36.71	0.26
Fish Passage	805	100-yr	280.00	8.47	13.03		13.23	0.003148	4.05	84.17	40.72	0.39
Fish Passage	805	500-yr	417.00	8.47	13.47		13.77	0.003981	4.94	102.41	42.48	0.45

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	789	10-cfs	10.00	10.17	10.91		11.01	0.024962	2.50	3.99	12.55	0.78
Fish Passage	789	60-cfs	48.00	10.17	11.46	11.46	11.70	0.018822	4.00	13.43	34.77	0.79
Fish Passage	789	2-yr	84.00	10.17	11.85		12.03	0.009837	3.75	27.02	36.30	0.61
Fish Passage	789	100-yr	280.00	10.17	12.83		13.15	0.007994	5.06	64.81	40.25	0.61
Fish Passage	789	500-yr	417.00	10.17	13.20		13.65	0.009405	6.09	79.83	41.72	0.67
Fish Passage	755	10-cfs	10.00	9.33	10.02	10.02	10.15	0.042122	2.95	3.39	12.36	0.99
Fish Passage	755	60-cfs	48.00	9.33	10.69		10.87	0.013036	3.52	15.86	35.05	0.66
Fish Passage	755	2-yr	84.00	9.33	10.99	10.86	11.18	0.010396	3.82	26.49	36.24	0.62
Fish Passage	755	100-yr	280.00	9.33	11.89	11.56	12.25	0.009648	5.39	60.88	39.86	0.66
Fish Passage	755	500-yr	417.00	9.33	12.35	11.93	12.81	0.009460	6.10	79.60	41.69	0.68
Fish Passage	747	10-cfs	10.00	7.51	10.07	8.24	10.07	0.000151	0.52	19.08	12.71	0.08
Fish Passage	747	60-cfs	48.00	7.51	10.77		10.81	0.000926	1.57	34.69	35.53	0.20
Fish Passage	747	2-yr	84.00	7.51	11.05		11.11	0.001586	2.24	44.51	36.62	0.26
Fish Passage	747	100-yr	280.00	7.51	11.93		12.17	0.003802	4.32	78.65	40.18	0.43
Fish Passage	747	500-yr	417.00	7.51	12.39		12.72	0.004567	5.18	97.45	42.01	0.48
Fish Passage	731	10-cfs	10.00	9.21	9.95		10.05	0.023785	2.47	4.05	12.57	0.77
Fish Passage	731	60-cfs	48.00	9.21	10.50	10.50	10.74	0.018818	4.00	13.43	34.77	0.79
Fish Passage	731	2-yr	84.00	9.21	10.74	10.74	11.03	0.018069	4.65	21.70	35.71	0.80
Fish Passage	731	100-yr	280.00	9.21	11.46		12.03	0.018956	6.78	48.72	38.62	0.90
Fish Passage	731	500-yr	417.00	9.21	11.83	11.81	12.57	0.018970	7.70	63.27	40.10	0.93
Fish Passage	698	10-cfs	10.00	8.40	9.09	9.09	9.22	0.042122	2.95	3.39	12.36	0.99
Fish Passage	698	60-cfs	48.00	8.40	9.76	9.69	9.94	0.012869	3.50	15.95	35.06	0.66
Fish Passage	698	2-yr	84.00	8.40	10.06	9.93	10.25	0.010312	3.81	26.58	36.25	0.62
Fish Passage	698	100-yr	280.00	8.40	10.98	10.63	11.33	0.009348	5.34	61.65	39.93	0.65
Fish Passage	698	500-yr	417.00	8.40	11.44		11.89	0.009246	6.06	80.45	41.78	0.67
Fish Passage	690	10-cfs	10.00	6.58	9.14	7.31	9.14	0.000151	0.52	19.06	12.71	0.08
Fish Passage	690	60-cfs	48.00	6.58	9.84		9.88	0.000923	1.57	34.74	35.54	0.20
Fish Passage	690	2-yr	84.00	6.58	10.12		10.19	0.001573	2.24	44.68	36.64	0.26
Fish Passage	690	100-yr	280.00	6.58	11.02		11.25	0.003756	4.31	79.23	40.23	0.43
Fish Passage	690	500-yr	417.00	6.58	11.48		11.80	0.004544	5.18	98.05	42.06	0.48
Fish Passage	674	10-cfs	10.00	8.28	9.02		9.12	0.024916	2.50	4.00	12.55	0.78
Fish Passage	674	60-cfs	48.00	8.28	9.57	9.57	9.81	0.018823	4.00	13.43	34.77	0.79
Fish Passage	674	2-yr	84.00	8.28	9.81	9.81	10.10	0.018087	4.65	21.70	35.71	0.80
Fish Passage	674	100-yr	280.00	8.28	10.58		11.11	0.016961	6.54	50.66	38.82	0.86

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	674	500-yr	417.00	8.28	10.97		11.64	0.017040	7.44	65.76	40.34	0.89
Fish Passage	635	10-cfs	10.00	7.32	8.01	8.01	8.14	0.042124	2.95	3.39	12.36	0.99
Fish Passage	635	60-cfs	48.00	7.32	8.68	8.61	8.86	0.013209	3.53	15.77	35.04	0.67
Fish Passage	635	2-yr	84.00	7.32	8.98	8.85	9.17	0.010516	3.84	26.38	36.23	0.63
Fish Passage	635	100-yr	280.00	7.32	9.92		10.26	0.008930	5.25	62.38	40.01	0.64
Fish Passage	635	500-yr	417.00	7.32	10.35		10.81	0.009273	6.05	80.02	41.73	0.67
Fish Passage	627	10-cfs	10.00	5.50	8.06	6.23	8.06	0.000151	0.52	19.06	12.71	0.08
Fish Passage	627	60-cfs	48.00	5.50	8.76		8.80	0.000929	1.57	34.64	35.52	0.20
Fish Passage	627	2-yr	84.00	5.50	9.03		9.10	0.001594	2.24	44.42	36.61	0.26
Fish Passage	627	100-yr	280.00	5.50	9.96		10.18	0.003620	4.25	80.02	40.31	0.42
Fish Passage	627	500-yr	417.00	5.50	10.39		10.72	0.004515	5.16	97.84	42.04	0.48
Fish Passage	611	10-cfs	10.00	7.20	7.94		8.04	0.024820	2.50	4.00	12.55	0.78
Fish Passage	611	60-cfs	48.00	7.20	8.49	8.49	8.73	0.018818	4.00	13.43	34.77	0.79
Fish Passage	611	2-yr	84.00	7.20	8.80		9.03	0.013296	4.17	24.27	36.00	0.70
Fish Passage	611	100-yr	280.00	7.20	9.66		10.07	0.011925	5.79	56.73	39.44	0.73
Fish Passage	611	500-yr	417.00	7.20	9.99		10.59	0.013968	6.95	69.95	40.76	0.81
Fish Passage	575	10-cfs	10.00	6.31	7.00	7.00	7.13	0.042483	2.96	3.38	12.36	1.00
Fish Passage	575	60-cfs	48.00	6.31	7.68		7.85	0.012847	3.50	15.96	35.06	0.66
Fish Passage	575	2-yr	84.00	6.31	7.98	7.84	8.17	0.009911	3.76	26.95	36.29	0.61
Fish Passage	575	100-yr	280.00	6.31	8.92	8.54	9.26	0.008839	5.24	62.76	40.05	0.63
Fish Passage	575	500-yr	417.00	6.31	9.39	8.91	9.82	0.008771	5.95	81.79	41.90	0.65
Fish Passage	567	10-cfs	10.00	4.49	7.05	5.22	7.05	0.000151	0.52	19.07	12.71	0.08
Fish Passage	567	60-cfs	48.00	4.49	7.75		7.79	0.000923	1.57	34.74	35.54	0.20
Fish Passage	567	2-yr	84.00	4.49	8.03		8.10	0.001558	2.23	44.84	36.66	0.26
Fish Passage	567	100-yr	280.00	4.49	8.95		9.18	0.003601	4.24	80.28	40.34	0.42
Fish Passage	567	500-yr	417.00	4.49	9.42		9.73	0.004342	5.10	99.37	42.19	0.47
Fish Passage	551	10-cfs	10.00	6.19	6.93		7.03	0.024247	2.48	4.03	12.56	0.77
Fish Passage	551	60-cfs	48.00	6.19	7.48	7.48	7.72	0.018823	4.00	13.43	34.77	0.79
Fish Passage	551	2-yr	84.00	6.19	7.83		8.03	0.011497	3.96	25.57	36.14	0.65
Fish Passage	551	100-yr	280.00	6.19	8.63		9.06	0.012627	5.91	55.81	39.35	0.75
Fish Passage	551	500-yr	417.00	6.19	9.05		9.60	0.012484	6.70	72.80	41.04	0.77
Fish Passage	498	10-cfs	10.00	4.89	5.58	5.58	5.71	0.041872	2.94	3.40	12.36	0.99
Fish Passage	498	60-cfs	48.00	4.89	6.25		6.43	0.013066	3.52	15.84	35.05	0.66

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage (Continued)

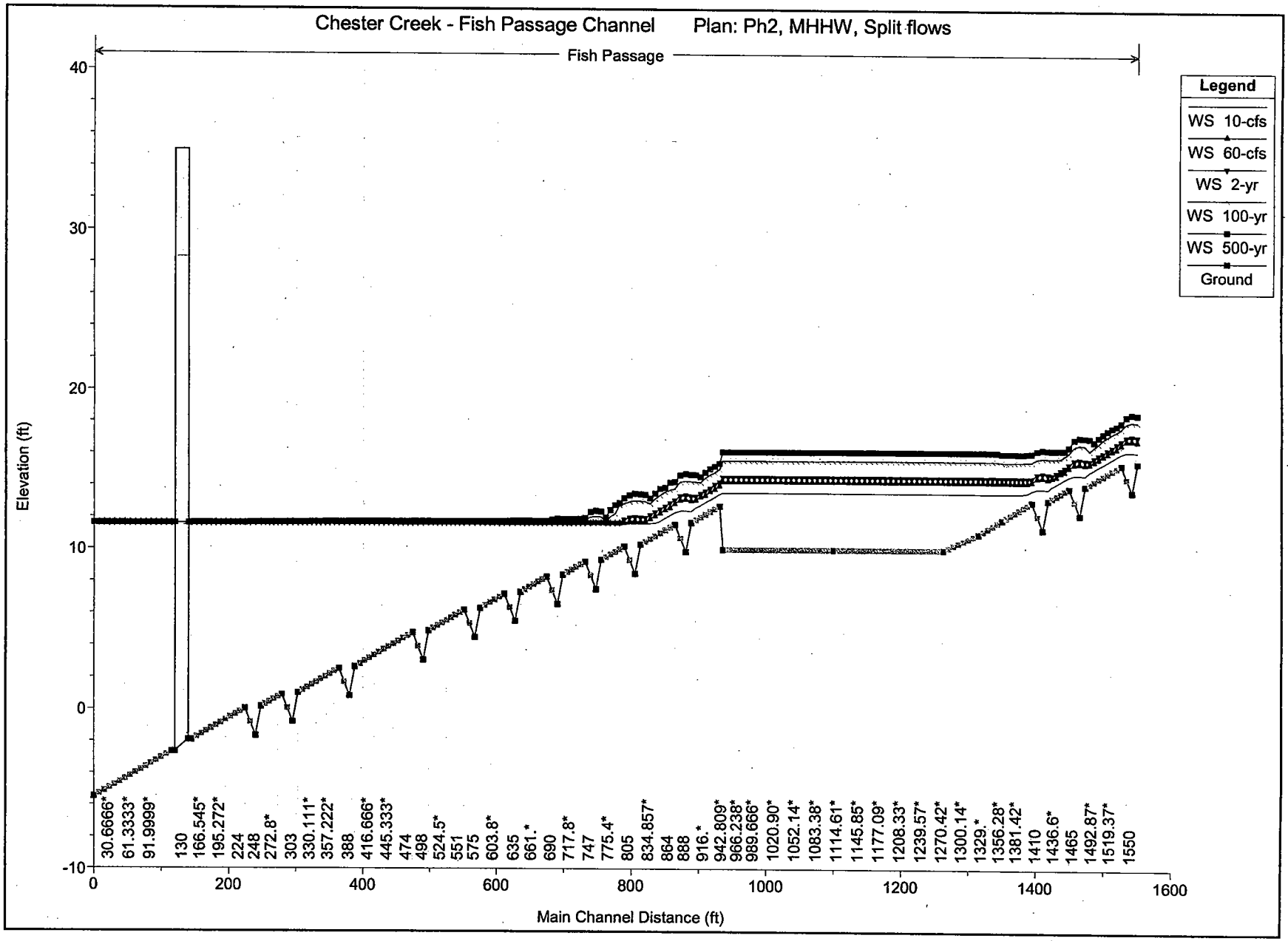
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	498	2-yr	84.00	4.89	6.54	6.42	6.73	0.010831	3.88	26.11	36.20	0.63
Fish Passage	498	100-yr	280.00	4.89	7.46	7.12	7.81	0.009590	5.38	60.93	39.86	0.66
Fish Passage	498	500-yr	417.00	4.89	7.91	7.49	8.37	0.009418	6.09	79.61	41.70	0.67
Fish Passage	490	10-cfs	10.00	3.06	5.63	3.79	5.63	0.000148	0.52	19.18	12.74	0.07
Fish Passage	490	60-cfs	48.00	3.06	6.33		6.37	0.000905	1.56	35.06	35.57	0.19
Fish Passage	490	2-yr	84.00	3.06	6.60		6.67	0.001564	2.23	44.76	36.65	0.26
Fish Passage	490	100-yr	280.00	3.06	7.50		7.73	0.003727	4.29	79.20	40.23	0.42
Fish Passage	490	500-yr	417.00	3.06	7.95		8.28	0.004494	5.15	98.00	42.06	0.48
Fish Passage	474	10-cfs	10.00	4.77	5.51		5.60	0.025540	2.52	3.96	12.54	0.79
Fish Passage	474	60-cfs	48.00	4.77	6.06	6.06	6.30	0.018821	4.00	13.43	34.77	0.79
Fish Passage	474	2-yr	84.00	4.77	6.33		6.59	0.015581	4.41	22.92	35.85	0.75
Fish Passage	474	100-yr	280.00	4.77	7.05		7.60	0.017854	6.65	49.73	38.72	0.88
Fish Passage	474	500-yr	417.00	4.77	7.43		8.13	0.017688	7.53	64.81	40.25	0.90
Fish Passage	388	10-cfs	10.00	2.65	3.34	3.34	3.47	0.043011	2.97	3.37	12.35	1.00
Fish Passage	388	60-cfs	48.00	2.65	4.04		4.21	0.011762	3.41	16.15	31.76	0.63
Fish Passage	388	2-yr	84.00	2.65	4.42	4.18	4.58	0.007609	3.47	28.56	33.28	0.54
Fish Passage	388	100-yr	280.00	2.65	5.65		5.90	0.005194	4.49	72.33	38.18	0.50
Fish Passage	388	500-yr	417.00	2.65	6.41		6.67	0.004098	4.76	108.59	53.45	0.46
Fish Passage	380	10-cfs	10.00	0.83	3.39	1.56	3.39	0.000151	0.52	19.07	12.71	0.08
Fish Passage	380	60-cfs	48.00	0.83	4.11		4.15	0.000917	1.58	33.66	29.91	0.20
Fish Passage	380	2-yr	84.00	0.83	4.46		4.53	0.001427	2.18	44.29	31.30	0.25
Fish Passage	380	100-yr	280.00	0.83	5.65		5.85	0.002678	3.93	84.51	36.07	0.37
Fish Passage	380	500-yr	417.00	0.83	6.40		6.64	0.002626	4.42	118.99	51.35	0.37
Fish Passage	364	10-cfs	10.00	2.53	3.27		3.37	0.024577	2.49	4.01	12.56	0.78
Fish Passage	364	60-cfs	48.00	2.53	3.79	3.77	4.07	0.023308	4.31	11.58	24.33	0.87
Fish Passage	364	2-yr	84.00	2.53	4.15		4.44	0.015667	4.57	20.58	25.76	0.76
Fish Passage	364	100-yr	280.00	2.53	5.19		5.73	0.012854	6.41	49.64	29.94	0.77
Fish Passage	364	500-yr	417.00	2.53	5.78		6.51	0.013121	7.61	68.05	43.50	0.81
Fish Passage	303	10-cfs	10.00	1.02	1.71	1.71	1.85	0.041926	2.98	3.36	12.35	0.99
Fish Passage	303	60-cfs	48.00	1.02	2.39		2.63	0.013934	3.93	12.79	15.10	0.71
Fish Passage	303	2-yr	84.00	1.02	2.84		3.14	0.011086	4.52	19.95	16.89	0.67
Fish Passage	303	100-yr	280.00	1.02	4.53		5.01	0.006813	5.98	54.10	23.63	0.60
Fish Passage	303	500-yr	417.00	1.02	5.38		5.93	0.005920	6.56	75.65	27.03	0.58

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	295	10-cfs	10.00	-0.80	1.76	-0.07	1.76	0.000150	0.52	19.10	12.72	0.08
Fish Passage	295	60-cfs	48.00	-0.80	2.51		2.55	0.001006	1.62	29.73	15.71	0.20
Fish Passage	295	2-yr	84.00	-0.80	2.97		3.05	0.001512	2.28	37.40	17.55	0.26
Fish Passage	295	100-yr	280.00	-0.80	4.65		4.91	0.002561	4.21	72.54	24.27	0.37
Fish Passage	295	500-yr	417.00	-0.80	5.48		5.84	0.002803	4.99	94.22	27.62	0.40
Fish Passage	279	10-cfs	10.00	0.90	1.64		1.74	0.024418	2.53	3.97	12.54	0.78
Fish Passage	279	60-cfs	48.00	0.90	2.13		2.46	0.024400	4.68	10.66	14.52	0.91
Fish Passage	279	2-yr	84.00	0.90	2.49		2.94	0.020978	5.52	16.14	15.96	0.90
Fish Passage	279	100-yr	280.00	0.90	4.27		4.81	0.008047	6.32	51.00	23.10	0.65
Fish Passage	279	500-yr	417.00	0.90	5.15		5.75	0.006620	6.80	72.67	26.59	0.61
Fish Passage	248	10-cfs	10.00	0.14	0.83	0.83	0.97	0.041927	2.98	3.36	12.35	0.99
Fish Passage	248	60-cfs	48.00	0.14	1.74		1.88	0.006675	3.13	16.28	16.00	0.51
Fish Passage	248	2-yr	84.00	0.14	2.36		2.52	0.004568	3.42	26.91	18.46	0.45
Fish Passage	248	100-yr	280.00	0.14	4.28		4.57	0.003317	4.73	69.96	26.18	0.43
Fish Passage	248	500-yr	417.00	0.14	5.17		5.52	0.003195	5.35	94.61	29.71	0.44
Fish Passage	240	10-cfs	10.00	-1.68	0.88	-0.95	0.88	0.000151	0.52	19.09	12.71	0.08
Fish Passage	240	60-cfs	48.00	-1.68	1.80		1.84	0.000756	1.48	32.53	16.41	0.18
Fish Passage	240	2-yr	84.00	-1.68	2.41		2.48	0.000978	2.00	43.34	18.86	0.21
Fish Passage	240	100-yr	280.00	-1.68	4.34		4.53	0.001562	3.59	87.07	26.56	0.29
Fish Passage	240	500-yr	417.00	-1.68	5.22		5.47	0.001768	4.28	111.99	30.08	0.32
Fish Passage	224	10-cfs	10.00	0.02	0.75		0.85	0.025604	2.57	3.91	12.53	0.80
Fish Passage	224	60-cfs	60.00	0.02	1.36	1.34	1.75	0.024501	5.10	12.31	14.97	0.93
Fish Passage	224	2-yr	112.00	0.02	1.78	1.78	2.37	0.023435	6.37	18.83	16.62	0.97
Fish Passage	224	100-yr	380.00	0.02	3.27	3.27	4.38	0.017397	9.03	48.19	22.61	0.94
Fish Passage	224	500-yr	559.00	0.02	3.97	3.97	5.31	0.016213	10.10	65.02	25.41	0.94
Fish Passage	145	10-cfs	10.00	-1.93	-1.07	-1.24	-1.02	0.008183	1.82	5.57	13.05	0.48
Fish Passage	145	60-cfs	60.00	-1.93	-0.33	-0.61	-0.10	0.010243	3.89	16.38	16.02	0.63
Fish Passage	145	2-yr	112.00	-1.93	0.17	-0.17	0.52	0.010304	4.92	24.82	18.00	0.67
Fish Passage	145	100-yr	380.00	-1.93	1.77	1.32	2.52	0.009920	7.52	58.81	24.42	0.73
Fish Passage	145	500-yr	559.00	-1.93	2.53	2.02	3.46	0.009615	8.50	78.47	27.45	0.74
Fish Passage	130		Bridge									
Fish Passage	115	10-cfs	10.00	-2.67	-1.94		-1.84	0.024859	2.55	3.95	12.54	0.79
Fish Passage	115	60-cfs	60.00	-2.67	-1.33	-1.35	-0.94	0.025064	5.14	12.22	14.94	0.94

HEC-RAS Plan: P2,LoYn,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	115	2-yr	112.00	-2.67	-0.91	-0.91	-0.32	0.023436	6.37	18.83	16.62	0.97
Fish Passage	115	100-yr	380.00	-2.67	0.58	0.58	1.69	0.017397	9.03	48.19	22.61	0.94
Fish Passage	115	500-yr	559.00	-2.67	1.28	1.28	2.62	0.016213	10.10	65.02	25.41	0.94
Fish Passage	0	10-cfs	10.00	-5.50	-4.77	-4.81	-4.67	0.025011	2.55	3.94	12.54	0.79
Fish Passage	0	60-cfs	60.00	-5.50	-4.16	-4.19	-3.77	0.025019	5.13	12.22	14.95	0.94
Fish Passage	0	2-yr	112.00	-5.50	-3.77	-3.74	-3.15	0.025063	6.50	18.41	16.52	1.00
Fish Passage	0	100-yr	380.00	-5.50	-2.47	-2.25	-1.11	0.023564	9.96	43.32	21.73	1.08
Fish Passage	0	500-yr	559.00	-5.50	-1.78	-1.55	-0.18	0.020988	10.98	59.29	24.49	1.06


Chester Creek - Fish Passage Channel
Plan: Ph2, MHHW, Split flows
Fish Passage
Legend
WS 10-cfs
WS 60-cfs
WS 2-yr
WS 100-yr
WS 500-yr
Ground
Elevation (ft)
Main Channel Distance (ft)
40
30
20
10
0
-10
0
200
400
600
800
1000
1200
1400
1600
30.6666*
61.3333*
91.9999*
130
166.545*
195.272*
224
248
272.8*
303
330.111*
357.222*
388
416.666*
445.333*
474
498
524.5*
551
575
603.8*
635
661.*
690
717.8*
747
775.4*
805
834.857*
864
888
916.*
942.809*
966.238*
989.666*
1020.90*
1052.14*
1083.38*
1114.61*
1145.85*
1177.09*
1208.33*
1239.57*
1270.42*
1300.14*
1329.*
1356.28*
1381.42*
1410
1436.6*
1465
1492.87*
1519.37*
1550

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	1550	10-cfs	10.00	15.50	16.19	16.19	16.32	0.042128	2.95	3.39	12.36	0.99
Fish Passage	1550	60-cfs	48.00	15.50	16.87	16.79	17.04	0.012849	3.50	15.96	35.06	0.66
Fish Passage	1550	2-yr	84.00	15.50	17.16	17.03	17.35	0.010296	3.81	26.59	36.25	0.62
Fish Passage	1550	100-yr	280.00	15.50	18.09	17.73	18.43	0.009301	5.33	61.71	39.94	0.65
Fish Passage	1550	500-yr	417.00	15.50	18.55	18.10	18.99	0.009182	6.05	80.56	41.79	0.67
Fish Passage	1542	10-cfs	10.00	13.68	16.24	14.41	16.24	0.000151	0.52	19.05	12.70	0.08
Fish Passage	1542	60-cfs	48.00	13.68	16.94		16.98	0.000923	1.57	34.74	35.54	0.20
Fish Passage	1542	2-yr	84.00	13.68	17.22		17.29	0.001572	2.23	44.69	36.64	0.26
Fish Passage	1542	100-yr	280.00	13.68	18.12		18.35	0.003742	4.30	79.30	40.24	0.43
Fish Passage	1542	500-yr	417.00	13.68	18.58		18.90	0.004519	5.17	98.17	42.07	0.48
Fish Passage	1526	10-cfs	10.00	15.38	16.12		16.21	0.025476	2.52	3.97	12.54	0.79
Fish Passage	1526	60-cfs	48.00	15.38	16.67	16.67	16.91	0.018823	4.00	13.43	34.77	0.79
Fish Passage	1526	2-yr	84.00	15.38	16.91	16.91	17.20	0.018087	4.65	21.70	35.71	0.80
Fish Passage	1526	100-yr	280.00	15.38	17.67		18.21	0.017674	6.63	49.97	38.75	0.87
Fish Passage	1526	500-yr	417.00	15.38	18.05		18.74	0.017595	7.52	65.07	40.28	0.90
Fish Passage	1473	10-cfs	10.00	14.03	14.72	14.72	14.85	0.042122	2.95	3.39	12.36	0.99
Fish Passage	1473	60-cfs	48.00	14.03	15.40	15.32	15.57	0.012834	3.50	15.97	35.06	0.66
Fish Passage	1473	2-yr	84.00	14.03	15.69	15.56	15.88	0.010314	3.81	26.57	36.25	0.62
Fish Passage	1473	100-yr	280.00	14.03	16.62	16.26	16.97	0.009190	5.30	61.91	39.96	0.65
Fish Passage	1473	500-yr	417.00	14.03	17.09		17.53	0.009023	6.01	80.93	41.82	0.66
Fish Passage	1465	10-cfs	10.00	12.21	14.77	12.94	14.77	0.000151	0.53	19.05	12.70	0.08
Fish Passage	1465	60-cfs	48.00	12.21	15.47		15.51	0.000923	1.57	34.75	35.54	0.20
Fish Passage	1465	2-yr	84.00	12.21	15.75		15.82	0.001574	2.24	44.68	36.64	0.26
Fish Passage	1465	100-yr	280.00	12.21	16.65		16.88	0.003718	4.29	79.48	40.26	0.42
Fish Passage	1465	500-yr	417.00	12.21	17.12		17.44	0.004470	5.15	98.54	42.11	0.48
Fish Passage	1449	10-cfs	10.00	13.91	14.64		14.74	0.025986	2.54	3.94	12.54	0.80
Fish Passage	1449	60-cfs	48.00	13.91	15.20	15.20	15.44	0.018823	4.00	13.43	34.77	0.79
Fish Passage	1449	2-yr	84.00	13.91	15.44	15.44	15.73	0.018087	4.65	21.70	35.71	0.80
Fish Passage	1449	100-yr	280.00	13.91	16.14	16.14	16.73	0.020181	6.94	47.83	38.53	0.93
Fish Passage	1449	500-yr	417.00	13.91	16.51	16.51	17.27	0.020211	7.88	62.16	39.99	0.96
Fish Passage	1418	10-cfs	10.00	13.13	13.82	13.82	13.95	0.042122	2.95	3.39	12.36	0.99
Fish Passage	1418	60-cfs	48.00	13.13	14.50	14.42	14.67	0.012831	3.50	15.97	35.06	0.66
Fish Passage	1418	2-yr	84.00	13.13	14.79	14.66	14.98	0.010557	3.84	26.36	36.23	0.63
Fish Passage	1418	100-yr	280.00	13.13	15.79		16.10	0.008138	5.09	64.52	40.22	0.61

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	1418	500-yr	417.00	13.13	16.30		16.69	0.007619	5.68	85.75	42.28	0.61
Fish Passage	1410	10-cfs	10.00	11.30	13.87	12.03	13.87	0.000149	0.52	19.18	12.74	0.07
Fish Passage	1410	60-cfs	48.00	11.30	14.58		14.61	0.000901	1.56	35.13	35.58	0.19
Fish Passage	1410	2-yr	84.00	11.30	14.85		14.92	0.001551	2.22	44.94	36.67	0.26
Fish Passage	1410	100-yr	280.00	11.30	15.82		16.03	0.003358	4.14	82.42	40.55	0.40
Fish Passage	1410	500-yr	417.00	11.30	16.33		16.62	0.003864	4.90	103.73	42.60	0.44
Fish Passage	1394	10-cfs	10.00	13.01	13.74	13.70	13.84	0.025768	2.53	3.95	12.54	0.79
Fish Passage	1394	60-cfs	48.00	13.01	14.30	14.30	14.54	0.018823	4.00	13.43	34.77	0.79
Fish Passage	1394	2-yr	84.00	13.01	14.54		14.83	0.017829	4.63	21.81	35.72	0.80
Fish Passage	1394	100-yr	280.00	13.01	15.57		15.93	0.009864	5.44	60.54	39.82	0.67
Fish Passage	1394	500-yr	417.00	13.01	16.10		16.53	0.008590	5.91	82.38	41.96	0.65
Fish Passage	1350	10-cfs	10.00	11.89	13.55		13.55	0.000150	0.46	26.34	36.23	0.07
Fish Passage	1350	60-cfs	48.00	11.89	14.26		14.27	0.000434	1.07	53.02	39.06	0.14
Fish Passage	1350	2-yr	84.00	11.89	14.54		14.57	0.000740	1.53	64.30	40.20	0.18
Fish Passage	1350	100-yr	280.00	11.89	15.54		15.65	0.001978	3.23	110.88	56.17	0.32
Fish Passage	1350	500-yr	417.00	11.89	16.07		16.22	0.002150	3.73	141.62	59.36	0.34
Fish Passage	1315	10-cfs	10.00	11.00	13.55		13.55	0.000001	0.05	227.32	148.37	0.01
Fish Passage	1315	60-cfs	48.00	11.00	14.26		14.26	0.000005	0.15	334.79	154.06	0.02
Fish Passage	1315	2-yr	84.00	11.00	14.55		14.55	0.000010	0.22	379.93	156.38	0.02
Fish Passage	1315	100-yr	280.00	11.00	15.59		15.60	0.000034	0.51	547.74	164.75	0.04
Fish Passage	1315	500-yr	417.00	11.00	16.15		16.15	0.000045	0.64	640.18	168.00	0.05
Fish Passage	1263	10-cfs	10.00	10.00	13.55		13.55	0.000000	0.06	233.90	148.37	0.01
Fish Passage	1263	60-cfs	48.00	10.00	14.26		14.26	0.000003	0.18	341.34	154.06	0.02
Fish Passage	1263	2-yr	84.00	10.00	14.55		14.55	0.000007	0.28	386.44	156.38	0.02
Fish Passage	1263	100-yr	280.00	10.00	15.59		15.60	0.000025	0.61	553.99	164.73	0.05
Fish Passage	1263	500-yr	417.00	10.00	16.14		16.15	0.000035	0.77	646.23	168.00	0.06
Fish Passage	1099	10-cfs	10.00	10.00	13.55		13.55	0.000000	0.06	233.89	148.37	0.01
Fish Passage	1099	60-cfs	48.00	10.00	14.26		14.26	0.000003	0.18	341.24	154.05	0.02
Fish Passage	1099	2-yr	84.00	10.00	14.55		14.55	0.000007	0.28	386.24	156.37	0.02
Fish Passage	1099	100-yr	280.00	10.00	15.59		15.59	0.000025	0.61	553.01	164.68	0.05
Fish Passage	1099	500-yr	417.00	10.00	16.13		16.14	0.000035	0.77	644.64	168.00	0.06
Fish Passage	935	10-cfs	10.00	10.00	13.55		13.55	0.000000	0.06	233.87	148.37	0.01
Fish Passage	935	60-cfs	48.00	10.00	14.26		14.26	0.000003	0.18	341.14	154.05	0.02

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	935	2-yr	84.00	10.00	14.55		14.55	0.000007	0.28	386.03	156.36	0.02
Fish Passage	935	100-yr	280.00	10.00	15.58		15.58	0.000025	0.61	552.04	164.63	0.05
Fish Passage	935	500-yr	417.00	10.00	16.13		16.13	0.000035	0.77	643.04	168.00	0.06
Fish Passage	930	10-cfs	10.00	12.70	13.44		13.54	0.023986	2.47	4.04	12.57	0.77
Fish Passage	930	60-cfs	48.00	12.70	13.99	13.99	14.23	0.018824	4.00	13.43	34.77	0.79
Fish Passage	930	2-yr	84.00	12.70	14.24		14.52	0.017423	4.59	22.00	35.74	0.79
Fish Passage	930	100-yr	280.00	12.70	15.02		15.53	0.016367	6.46	51.26	38.88	0.84
Fish Passage	930	500-yr	417.00	12.70	15.40		16.07	0.016607	7.38	66.32	40.40	0.87
Fish Passage	888	10-cfs	10.00	11.67	12.36	12.36	12.49	0.042122	2.95	3.39	12.36	0.99
Fish Passage	888	60-cfs	48.00	11.67	13.03	12.96	13.21	0.012999	3.51	15.88	35.05	0.66
Fish Passage	888	2-yr	84.00	11.67	13.33	13.20	13.52	0.010312	3.81	26.57	36.25	0.62
Fish Passage	888	100-yr	280.00	11.67	14.24		14.60	0.009515	5.37	61.20	39.89	0.66
Fish Passage	888	500-yr	417.00	11.67	14.70		15.15	0.009454	6.10	79.70	41.70	0.68
Fish Passage	880	10-cfs	10.00	9.85	12.41	10.58	12.41	0.000151	0.52	19.06	12.70	0.08
Fish Passage	880	60-cfs	48.00	9.85	13.11		13.15	0.000925	1.57	34.70	35.53	0.20
Fish Passage	880	2-yr	84.00	9.85	13.39		13.46	0.001582	2.24	44.57	36.63	0.26
Fish Passage	880	100-yr	280.00	9.85	14.28		14.51	0.003782	4.32	78.91	40.20	0.43
Fish Passage	880	500-yr	417.00	9.85	14.73		15.06	0.004589	5.20	97.47	42.01	0.48
Fish Passage	864	10-cfs	10.00	11.55	12.29		12.39	0.025132	2.51	3.98	12.55	0.78
Fish Passage	864	60-cfs	48.00	11.55	12.84	12.84	13.08	0.018823	4.00	13.43	34.77	0.79
Fish Passage	864	2-yr	84.00	11.55	13.08	13.08	13.37	0.018084	4.65	21.70	35.71	0.80
Fish Passage	864	100-yr	280.00	11.55	13.78	13.78	14.37	0.020160	6.93	47.82	38.52	0.93
Fish Passage	864	500-yr	417.00	11.55	14.23		14.91	0.017222	7.47	65.46	40.32	0.89
Fish Passage	813	10-cfs	10.00	10.29	11.61		11.62	0.000719	0.80	14.26	34.87	0.15
Fish Passage	813	60-cfs	48.00	10.29	11.72	11.58	11.86	0.009115	3.10	18.37	35.34	0.56
Fish Passage	813	2-yr	84.00	10.29	11.98	11.82	12.15	0.009284	3.67	27.57	36.36	0.59
Fish Passage	813	100-yr	280.00	10.29	13.00		13.30	0.007300	4.91	66.83	40.45	0.58
Fish Passage	813	500-yr	417.00	10.29	13.44		13.84	0.007836	5.73	84.89	42.20	0.62
Fish Passage	805	10-cfs	10.00	8.47	11.61		11.61	0.000053	0.36	30.31	35.03	0.05
Fish Passage	805	60-cfs	48.00	8.47	11.78		11.81	0.000842	1.52	36.22	35.70	0.19
Fish Passage	805	2-yr	84.00	8.47	12.03		12.10	0.001515	2.21	45.35	36.71	0.26
Fish Passage	805	100-yr	280.00	8.47	13.03		13.23	0.003153	4.05	84.13	40.72	0.39
Fish Passage	805	500-yr	417.00	8.47	13.47		13.77	0.003981	4.94	102.41	42.48	0.45

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	789	10-cfs	10.00	10.17	11.60		11.61	0.000399	0.65	18.31	35.33	0.12
Fish Passage	789	60-cfs	48.00	10.17	11.66		11.77	0.007027	2.83	20.32	35.56	0.50
Fish Passage	789	2-yr	84.00	10.17	11.85		12.03	0.009594	3.71	27.25	36.33	0.60
Fish Passage	789	100-yr	280.00	10.17	12.83		13.15	0.008019	5.07	64.74	40.24	0.61
Fish Passage	789	500-yr	417.00	10.17	13.20		13.65	0.009405	6.09	79.83	41.72	0.67
Fish Passage	755	10-cfs	10.00	9.33	11.60		11.60	0.000023	0.24	49.36	38.68	0.03
Fish Passage	755	60-cfs	48.00	9.33	11.63		11.64	0.000506	1.13	50.31	38.78	0.15
Fish Passage	755	2-yr	84.00	9.33	11.68		11.72	0.001379	1.89	52.31	38.99	0.24
Fish Passage	755	100-yr	280.00	9.33	12.01	11.56	12.32	0.007724	5.00	65.49	40.32	0.60
Fish Passage	755	500-yr	417.00	9.33	12.35	11.93	12.81	0.009489	6.11	79.53	41.69	0.68
Fish Passage	747	10-cfs	10.00	7.51	11.60		11.60	0.000008	0.19	65.49	38.84	0.02
Fish Passage	747	60-cfs	48.00	7.51	11.63		11.64	0.000179	0.88	66.46	38.94	0.09
Fish Passage	747	2-yr	84.00	7.51	11.68		11.71	0.000503	1.49	68.59	39.16	0.15
Fish Passage	747	100-yr	280.00	7.51	12.04		12.25	0.003271	4.10	82.92	40.60	0.40
Fish Passage	747	500-yr	417.00	7.51	12.39		12.72	0.004577	5.19	97.38	42.00	0.48
Fish Passage	731	10-cfs	10.00	9.21	11.60		11.60	0.000018	0.22	54.01	39.16	0.03
Fish Passage	731	60-cfs	48.00	9.21	11.62		11.63	0.000392	1.03	54.70	39.23	0.13
Fish Passage	731	2-yr	84.00	9.21	11.66		11.70	0.001101	1.75	56.27	39.39	0.22
Fish Passage	731	100-yr	280.00	9.21	11.82		12.16	0.008762	5.22	62.77	40.05	0.63
Fish Passage	731	500-yr	417.00	9.21	11.95		12.58	0.015398	7.18	67.74	40.54	0.84
Fish Passage	698	10-cfs	10.00	8.40	11.60		11.60	0.000004	0.13	87.03	42.40	0.01
Fish Passage	698	60-cfs	48.00	8.40	11.61		11.62	0.000095	0.64	87.64	42.46	0.07
Fish Passage	698	2-yr	84.00	8.40	11.65		11.67	0.000332	1.21	89.36	53.82	0.13
Fish Passage	698	100-yr	280.00	8.40	11.79		11.95	0.002887	3.69	96.92	54.66	0.38
Fish Passage	698	500-yr	417.00	8.40	11.87		12.18	0.005592	5.23	101.36	55.15	0.53
Fish Passage	690	10-cfs	10.00	6.58	11.60		11.60	0.000002	0.12	103.31	42.56	0.01
Fish Passage	690	60-cfs	48.00	6.58	11.61		11.62	0.000059	0.61	103.94	53.82	0.05
Fish Passage	690	2-yr	84.00	6.58	11.65		11.67	0.000171	1.04	106.06	54.06	0.09
Fish Passage	690	100-yr	280.00	6.58	11.80		11.92	0.001548	3.20	114.06	54.94	0.28
Fish Passage	690	500-yr	417.00	6.58	11.89		12.13	0.003056	4.57	118.86	55.46	0.40
Fish Passage	674	10-cfs	10.00	8.28	11.60		11.60	0.000004	0.14	92.94	54.22	0.01
Fish Passage	674	60-cfs	48.00	8.28	11.61		11.62	0.000094	0.66	93.60	54.29	0.07
Fish Passage	674	2-yr	84.00	8.28	11.65		11.67	0.000269	1.12	95.73	54.53	0.12
Fish Passage	674	100-yr	280.00	8.28	11.74		11.88	0.002557	3.53	100.83	55.09	0.36

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	674	500-yr	417.00	8.28	11.74		12.05	0.005695	5.26	100.69	55.07	0.54
Fish Passage	635	10-cfs	10.00	7.32	11.60		11.60	0.000001	0.08	147.75	59.98	0.01
Fish Passage	635	60-cfs	48.00	7.32	11.61		11.61	0.000023	0.39	148.42	60.05	0.04
Fish Passage	635	2-yr	84.00	7.32	11.65		11.65	0.000067	0.68	150.56	60.26	0.06
Fish Passage	635	100-yr	280.00	7.32	11.74		11.79	0.000665	2.17	156.17	60.82	0.19
Fish Passage	635	500-yr	417.00	7.32	11.75		11.87	0.001454	3.21	156.91	60.89	0.29
Fish Passage	627	10-cfs	10.00	5.50	11.60		11.60	0.000001	0.08	164.74	60.22	0.01
Fish Passage	627	60-cfs	48.00	5.50	11.61		11.61	0.000015	0.36	165.40	60.29	0.03
Fish Passage	627	2-yr	84.00	5.50	11.65		11.65	0.000045	0.63	167.51	60.50	0.05
Fish Passage	627	100-yr	280.00	5.50	11.74		11.79	0.000458	2.03	173.12	61.05	0.16
Fish Passage	627	500-yr	417.00	5.50	11.75		11.86	0.001000	3.00	174.01	61.14	0.24
Fish Passage	611	10-cfs	10.00	7.20	11.60		11.60	0.000001	0.08	154.99	60.70	0.01
Fish Passage	611	60-cfs	48.00	7.20	11.61		11.61	0.000020	0.37	155.64	60.76	0.03
Fish Passage	611	2-yr	84.00	7.20	11.64		11.65	0.000058	0.64	157.69	60.97	0.06
Fish Passage	611	100-yr	280.00	7.20	11.73		11.78	0.000588	2.07	162.68	61.46	0.18
Fish Passage	611	500-yr	417.00	7.20	11.73		11.84	0.001306	3.09	162.65	61.45	0.27
Fish Passage	575	10-cfs	10.00	6.31	11.60		11.60	0.000000	0.06	211.39	66.04	0.00
Fish Passage	575	60-cfs	48.00	6.31	11.61		11.61	0.000008	0.27	212.03	66.10	0.02
Fish Passage	575	2-yr	84.00	6.31	11.64		11.64	0.000023	0.47	214.06	66.28	0.04
Fish Passage	575	100-yr	280.00	6.31	11.72		11.74	0.000242	1.52	219.09	66.74	0.12
Fish Passage	575	500-yr	417.00	6.31	11.72		11.78	0.000535	2.26	219.48	66.77	0.18
Fish Passage	567	10-cfs	10.00	4.49	11.60		11.60	0.000000	0.05	228.62	66.28	0.00
Fish Passage	567	60-cfs	48.00	4.49	11.61		11.61	0.000006	0.26	229.25	66.34	0.02
Fish Passage	567	2-yr	84.00	4.49	11.64		11.64	0.000018	0.45	231.25	66.52	0.03
Fish Passage	567	100-yr	280.00	4.49	11.71		11.74	0.000186	1.46	236.21	66.96	0.11
Fish Passage	567	500-yr	417.00	4.49	11.72		11.77	0.000410	2.17	236.69	67.01	0.16
Fish Passage	551	10-cfs	10.00	6.19	11.60		11.60	0.000000	0.05	219.36	66.76	0.00
Fish Passage	551	60-cfs	48.00	6.19	11.61		11.61	0.000007	0.26	219.97	66.82	0.02
Fish Passage	551	2-yr	84.00	6.19	11.64		11.64	0.000021	0.45	221.90	66.99	0.04
Fish Passage	551	100-yr	280.00	6.19	11.71		11.74	0.000219	1.46	226.73	67.42	0.12
Fish Passage	551	500-yr	417.00	6.19	11.71		11.77	0.000483	2.18	227.01	67.45	0.17
Fish Passage	498	10-cfs	10.00	4.89	11.60		11.60	0.000000	0.04	311.21	74.56	0.00
Fish Passage	498	60-cfs	48.00	4.89	11.61		11.61	0.000002	0.18	311.78	74.61	0.01

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	498	2-yr	84.00	4.89	11.63		11.63	0.000007	0.31	313.58	74.75	0.02
Fish Passage	498	100-yr	280.00	4.89	11.69		11.71	0.000079	1.02	318.25	75.12	0.07
Fish Passage	498	500-yr	417.00	4.89	11.71		11.74	0.000173	1.52	319.27	75.21	0.11
Fish Passage	490	10-cfs	10.00	3.06	11.60		11.60	0.000000	0.04	329.53	74.86	0.00
Fish Passage	490	60-cfs	48.00	3.06	11.61		11.61	0.000002	0.17	330.09	74.91	0.01
Fish Passage	490	2-yr	84.00	3.06	11.63		11.63	0.000006	0.30	331.85	75.05	0.02
Fish Passage	490	100-yr	280.00	3.06	11.69		11.70	0.000065	1.00	336.44	75.41	0.06
Fish Passage	490	500-yr	417.00	3.06	11.71		11.73	0.000144	1.48	337.55	75.50	0.10
Fish Passage	474	10-cfs	10.00	4.77	11.60		11.60	0.000000	0.04	320.20	75.28	0.00
Fish Passage	474	60-cfs	48.00	4.77	11.61		11.61	0.000002	0.17	320.74	75.32	0.01
Fish Passage	474	2-yr	84.00	4.77	11.63		11.63	0.000007	0.30	322.42	75.46	0.02
Fish Passage	474	100-yr	280.00	4.77	11.69		11.70	0.000073	0.99	326.85	75.81	0.07
Fish Passage	474	500-yr	417.00	4.77	11.71		11.73	0.000159	1.48	328.15	75.91	0.10
Fish Passage	388	10-cfs	10.00	2.65	11.60		11.60	0.000000	0.02	466.93	84.60	0.00
Fish Passage	388	60-cfs	48.00	2.65	11.60		11.61	0.000001	0.12	467.34	84.63	0.01
Fish Passage	388	2-yr	84.00	2.65	11.62		11.62	0.000002	0.21	468.61	84.72	0.01
Fish Passage	388	100-yr	280.00	2.65	11.66		11.67	0.000023	0.68	472.36	84.98	0.04
Fish Passage	388	500-yr	417.00	2.65	11.70		11.71	0.000051	1.01	475.01	85.17	0.06
Fish Passage	380	10-cfs	10.00	0.83	11.60		11.60	0.000000	0.03	466.98	82.54	0.00
Fish Passage	380	60-cfs	48.00	0.83	11.60		11.60	0.000001	0.12	467.37	82.57	0.01
Fish Passage	380	2-yr	84.00	0.83	11.62		11.62	0.000002	0.21	468.56	82.65	0.01
Fish Passage	380	100-yr	280.00	0.83	11.66		11.67	0.000023	0.70	472.12	82.91	0.04
Fish Passage	380	500-yr	417.00	0.83	11.69		11.70	0.000049	1.03	474.61	83.09	0.06
Fish Passage	364	10-cfs	10.00	2.53	11.60		11.60	0.000000	0.03	422.82	78.42	0.00
Fish Passage	364	60-cfs	48.00	2.53	11.60		11.60	0.000001	0.13	423.15	78.45	0.01
Fish Passage	364	2-yr	84.00	2.53	11.62		11.62	0.000003	0.23	424.20	78.53	0.01
Fish Passage	364	100-yr	280.00	2.53	11.66		11.66	0.000029	0.76	427.38	78.77	0.05
Fish Passage	364	500-yr	417.00	2.53	11.69		11.70	0.000063	1.13	429.58	78.94	0.07
Fish Passage	303	10-cfs	10.00	1.02	11.60		11.60	0.000000	0.04	321.26	51.92	0.00
Fish Passage	303	60-cfs	48.00	1.02	11.60		11.60	0.000002	0.20	321.39	51.93	0.01
Fish Passage	303	2-yr	84.00	1.02	11.61		11.61	0.000005	0.35	321.80	51.96	0.02
Fish Passage	303	100-yr	280.00	1.02	11.64		11.65	0.000053	1.17	323.34	52.08	0.06
Fish Passage	303	500-yr	417.00	1.02	11.65		11.68	0.000117	1.74	323.74	52.11	0.10

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	295	10-cfs	10.00	-0.80	11.60		11.60	0.000000	0.04	337.93	52.08	0.00
Fish Passage	295	60-cfs	48.00	-0.80	11.60		11.60	0.000001	0.18	338.05	52.09	0.01
Fish Passage	295	2-yr	84.00	-0.80	11.61		11.61	0.000004	0.32	338.43	52.12	0.02
Fish Passage	295	100-yr	280.00	-0.80	11.64		11.65	0.000044	1.07	339.97	52.24	0.06
Fish Passage	295	500-yr	417.00	-0.80	11.65		11.68	0.000096	1.59	340.34	52.26	0.08
Fish Passage	279	10-cfs	10.00	0.90	11.60		11.60	0.000000	0.04	327.52	52.40	0.00
Fish Passage	279	60-cfs	48.00	0.90	11.60		11.60	0.000001	0.20	327.63	52.41	0.01
Fish Passage	279	2-yr	84.00	0.90	11.61		11.61	0.000005	0.35	327.94	52.43	0.02
Fish Passage	279	100-yr	280.00	0.90	11.64		11.65	0.000050	1.15	329.49	52.55	0.06
Fish Passage	279	500-yr	417.00	0.90	11.64		11.67	0.000111	1.71	329.80	52.57	0.09
Fish Passage	248	10-cfs	10.00	0.14	11.60		11.60	0.000000	0.04	368.50	55.44	0.00
Fish Passage	248	60-cfs	48.00	0.14	11.60		11.60	0.000001	0.18	368.56	55.44	0.01
Fish Passage	248	2-yr	84.00	0.14	11.60		11.61	0.000003	0.31	368.73	55.46	0.02
Fish Passage	248	100-yr	280.00	0.14	11.63		11.64	0.000037	1.03	370.36	55.57	0.05
Fish Passage	248	500-yr	417.00	0.14	11.64		11.66	0.000082	1.53	370.52	55.59	0.08
Fish Passage	240	10-cfs	10.00	-1.68	11.60		11.60	0.000000	0.03	385.30	55.60	0.00
Fish Passage	240	60-cfs	48.00	-1.68	11.60		11.60	0.000001	0.16	385.35	55.60	0.01
Fish Passage	240	2-yr	84.00	-1.68	11.60		11.60	0.000003	0.29	385.49	55.61	0.01
Fish Passage	240	100-yr	280.00	-1.68	11.63		11.64	0.000031	0.95	387.13	55.73	0.05
Fish Passage	240	500-yr	417.00	-1.68	11.64		11.66	0.000069	1.41	387.25	55.74	0.07
Fish Passage	224	10-cfs	10.00	0.02	11.60		11.60	0.000000	0.04	375.18	55.92	0.00
Fish Passage	224	60-cfs	60.00	0.02	11.60		11.60	0.000002	0.22	375.21	55.92	0.01
Fish Passage	224	2-yr	112.00	0.02	11.60		11.60	0.000006	0.41	375.28	55.93	0.02
Fish Passage	224	100-yr	380.00	0.02	11.62		11.64	0.000065	1.38	376.30	56.00	0.07
Fish Passage	224	500-yr	559.00	0.02	11.61		11.65	0.000141	2.03	375.85	55.97	0.11
Fish Passage	145	10-cfs	10.00	-1.93	11.60	-1.24	11.60	0.000000	0.03	491.83	63.72	0.00
Fish Passage	145	60-cfs	60.00	-1.93	11.60	-0.61	11.60	0.000001	0.17	491.83	63.72	0.01
Fish Passage	145	2-yr	112.00	-1.93	11.60	-0.17	11.60	0.000003	0.32	491.83	63.72	0.02
Fish Passage	145	100-yr	380.00	-1.93	11.60	1.32	11.61	0.000032	1.07	491.88	63.72	0.05
Fish Passage	145	500-yr	559.00	-1.93	11.60	2.02	11.63	0.000069	1.58	491.94	63.73	0.08
Fish Passage	130		Bridge									
Fish Passage	115	10-cfs	10.00	-2.67	11.60		11.60	0.000000	0.03	540.08	66.68	0.00
Fish Passage	115	60-cfs	60.00	-2.67	11.60		11.60	0.000001	0.16	540.08	66.68	0.01

HEC-RAS Plan: P2,MHHW,Splt River: Chester Crk Reach: Fish Passage (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Fish Passage	115	2-yr	112.00	-2.67	11.60		11.60	0.000002	0.29	540.07	66.68	0.01
Fish Passage	115	100-yr	380.00	-2.67	11.60		11.61	0.000025	0.99	540.02	66.68	0.05
Fish Passage	115	500-yr	559.00	-2.67	11.60		11.62	0.000054	1.45	539.96	66.67	0.07
Fish Passage	0	10-cfs	10.00	-5.50	11.60	-4.81	11.60	0.000000	0.02	744.80	78.00	0.00
Fish Passage	0	60-cfs	60.00	-5.50	11.60	-4.19	11.60	0.000000	0.12	744.80	78.00	0.00
Fish Passage	0	2-yr	112.00	-5.50	11.60	-3.74	11.60	0.000001	0.22	744.80	78.00	0.01
Fish Passage	0	100-yr	380.00	-5.50	11.60	-2.25	11.60	0.000011	0.73	744.80	78.00	0.03
Fish Passage	0	500-yr	559.00	-5.50	11.60	-1.55	11.61	0.000023	1.07	744.80	78.00	0.05

CHANNEL GEOMETRY

Section	BANK SLOPE H	BANK SLOPE V	CHANNEL WIDTH (Feet)	WATER DEPTH (Feet)	AREA (Feet2)	WETTED PERIM. (Feet)	HYDR. RADIUS (Feet)	AVG SLOPE	ROUGH (n)	WATER VEL (f/s)	Q (cfs)	W/D Ratio	Valley Slope
75-cfs	1.00	1	12.0	1.11	14.55	15.1	0.961	0.0180	0.038	5.1	74.6	11	0.020
2-year	1.00	1	15.0	1.24	20.14	18.5	1.088	0.0180	0.038	5.6	112.1	12	0.020

Empirical equations	Min Bend Length	Max Bend Length	Rc	Rc/W	Meander Wavelength f(w)	Meander Wavelength f(Rc)	Belt Width f(Lm)	Sinuosity f(slope)	Rc Using sin, L	Sinuosity Using Lm, Lb
	120	168	24	2.02	121.3	109.9	70.5	1.1	32.8	2.0
	150	210	31	2.08	155.7	141.1	90.5	1.1	42.1	2.4

Means of Calculation:			Source:
Meander Length:	Lb	10 to 14 * Width	Pool:Riffle spacing 5-7 widths
Radius of Curvature:	Rc	1.5*(width^1.12)	Williams (1986)
Meander Wavelength (1)	Lm	7.5*(width^1.12)	Williams (1986)
Meander Wavelength (2)	Lm	4.53*average Rc	Williams (1986)
Belt Width	B	0.61*avg meander wavelength	Williams (1986)
Sinuosity (1)	K	Valley Slope/Channel slope	
Rc using sinuosity, L	Rc	((Lm(K^1.5))/(13*(K-1)^0.5))	Langbein and Leopold (1966) (from Rosgen)
Sinuosity (2)	K	(2*Meander Length)/Wavelength	

Goals	Slope	Sin	W:D
1,3	<.02	>1.2	>12
2	<.02	>1.5	<12

Stevens and Simons Riprap Sizing Procedure
Ref: *Erosion and Sedimentation*, P.Y. Julien, 1995, pg 121-126

Equations:

$$eta = \frac{21 * tau}{(gamma(s) - gamma) * Ds}$$

$$beta = \arctan \frac{\cos(lambda)}{\frac{(M + N)\sin(theta)}{N * eta * \tan(phi)} + SIN(lambda)}$$

$$eta' = eta * \frac{(M/N) + \sin(lambda + beta)}{1 + (M/N)}$$

$$s.f. = \frac{\cos(theta) * \tan(phi)}{eta' * \tan(phi) + \sin(theta) * \cos(beta)}$$

Where:

theta =	bank angle, degrees
phi =	angle of repose, degrees
lambda =	streamline angle down from horizontal, degrees
tau =	shear stress on bed, psf
gamma =	62.4 pcf
s.g. =	2.5
gamma(s) =	156 pcf

SUMMARY
Stevens & Simons Rock Sizing Calculations

Legend: Entered values / Result

Project XS	bed shear, tau	Particle Size, D50 =		Theta			Phi, angle of repose		lambda =		M/N =	eta	beta =		eta' =	F.S. =
	psf	ft	in	H:1V	degrees	radians	degrees	radians	degrees	radians	assumed		degrees	radians		
10+00 to 23+00, 100-year criteria																
bed	3.40	1.25	15.0	50.00	1.14576	0.019997	36	0.628319	90	1.570796	1.0	0.61026	0.00	0.0000	0.610256	**1.57**
bank	2.55	2.75	33.0	2.00	26.56499	0.463647	39	0.680678	0	0	1.0	0.20804	10.67	0.1862	0.123275	**1.34**
fp	2.80	1.75	21.0	20.00	2.862399	0.049958	36	0.628319	0	0	1.0	0.35897	69.05	1.2051	0.347105	**2.69**
23+00 to 25+50, 500-year criteria																
bed	4.70	1.50	18.0	50.00	1.14576	0.019997	41	0.715585	90	1.570796	1.0	0.70299	0.00	0.0000	0.702991	**1.38**
bank	3.53	2.75	33.0	2.00	26.56499	0.463647	41	0.715585	0	0	1.0	0.28759	15.62	0.2725	0.182501	**1.32**

Channel 10+00 to 22+20
100-yr criteria

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2.0

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Riprap

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D_{100} = 1.30ft GSD

D_{90} = 1.23ft calc

PROGRAM OUTPUT

========== USCOE Method ==========

Input Parameters:

Run Name: CHESTER1 Description: CFF channel

Velocity	Local
Channel Type	N/A
Straight Channel	N/A
Bend Angle, ø	N/A
Local Channel Velocity, ft/sec	9.00
Bottom Width, ft	N/A
Minimum Centerline Bend Radius, ft	N/A
Water Surface Width, ft	N/A
Unit Weight of Stone, lbs/cu ft	165.00
Riprap Layer Thickness	1.20
Local Flow Depth, ft	2.50
Cotangent of Sideslope	2.00
Safety Factor	1.10

Output Results:

Computed Local Depth Average Velocity, ft/sec	N/A
Local Velocity / Avg. Channel Velocity	N/A
Correction for Layer Thickness	0.94
Side Slope Correction Factor	1.18
Correction for Secondary Currents	1.22

*** Using Gradation from COE ETL 1110-2-120 ***

Computed D30, ft	0.61	
Specific Weight, pcf	165.00	
Layer Thickness, ft	2.250	(Increased by 50%)
Selected Minimum D30, ft	0.73	
Selected Minimum D90, ft	1.06	

Percent Lighter by Weight	Stone Weight, lbs Minimum	Maximum
W100	117	292
W50	58	86
W15	18	43

========== ASCE Method

==========

Input Parameters:

Run Name: CHESTER1 Description: CFF channel

Local Depth Averaged Velocity, ft/sec	9.00
Unit Weight of Stone, lbs/cu ft	165.00
Cotangent of Sideslope	2.00

Output Results:

Computed D50, ft	0.59

*** Using Gradation from COE ETL 1110-2-120 ***

Computed D30, ft	0.49
Specific Weight, pcf	165.00
Layer Thickness, ft	1.00
Selected Minimum D30, ft	0.49
Selected Minimum D90, ft	0.71

Percent Lighter by Weight	Stone Weight, lbs Minimum	Maximum
W100	35	86
W50	17	26
W15	5	13

========== Isbash Method
==========

Input Parameters:

Run Name: CHESTER1 Description: CFF channel

Average Channel Velocity, ft/sec	9.00
Unit Weight of Stone, lbs/cu ft	165.00
Turbulence Level	High

Output Results:

Computed D50, ft	1.03

*** Using Gradation from COE ETL 1110-2-120 ***

Computed D30, ft	0.85
Specific Weight, pcf	165.00
Layer Thickness, ft	1.75
Selected Minimum D30, ft	0.85
Selected Minimum D90, ft	1.23

Percent Lighter by Weight	Stone Weight, lbs Minimum	Maximum
W100	185	463
W50	93	137
W15	29	69

HEC-11 Method

Input Parameters:

Run Name: CHESTER1 Description: CFF channel

Average Channel Velocity, ft/sec	9.00
Average Flow Depth, ft	2.50
Unit Weight of Stone, lbs/cu ft	165.00
Material Angle of Repose, ø	41.00
Cotangent of Sideslope	2.00
Safety Factor	1.10

Output Results:

Computed D50, ft 0.65

*** Using FHWA Gradation ***

Gradation Class Facing
Layer Thickness, ft 2.14 (Increased by 50%)

Percent Smaller by Size	Rock Size, ft	Rock Size, lbs
D100	1.30	200
D50	0.95	75
D10	0.40	5

Channel 22+20 to d/s limit
500-yr criteria

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PROGRAM OUTPUT

D100 = 1.80 ft GSD
D90 = 2.12 ft calc

========== USCOE Method
==========

Input Parameters:

Run Name: CHESTER3 Description: d/s channel

	Local
Velocity	
Channel Type	N/A
Straight Channel	N/A
Bend Angle, ø	N/A
Local Channel Velocity, ft/sec	11.50
Bottom Width, ft	N/A
Minimum Centerline Bend Radius, ft	N/A
Water Surface Width, ft	N/A
Unit Weight of Stone, lbs/cu ft	165.00
Riprap Layer Thickness	1.20
Local Flow Depth, ft	2.50
Cotangent of Sideslope	2.00
Safety Factor	1.10

Output Results:

Computed Local Depth Average Velocity, ft/sec	N/A
Local Velocity / Avg. Channel Velocity	N/A
Correction for Layer Thickness	0.94
Side Slope Correction Factor	1.18
Correction for Secondary Currents	1.22

*** Using Gradation from COE ETL 1110-2-120 ***

Computed D30, ft	1.13	
Specific Weight, pcf	165.00	
Layer Thickness, ft	3.750	(Increased by 50%)
Selected Minimum D30, ft	1.22	
Selected Minimum D90, ft	1.76	

Percent Lighter by Weight	Stone Weight, lbs Minimum	Maximum
W100	540	1,350
W50	270	400
W15	84	200

========== ASCE Method

==========

Input Parameters:

Run Name: CHESTER3 Description: d/s channel

Local Depth Averaged Velocity, ft/sec	11.50
Unit Weight of Stone, lbs/cu ft	165.00
Cotangent of Sideslope	2.00

Output Results:

Computed D50, ft	0.97

*** Using Gradation from COE ETL 1110-2-120 ***

Computed D30, ft	0.80
Specific Weight, pcf	165.00
Layer Thickness, ft	1.75
Selected Minimum D30, ft	0.85
Selected Minimum D90, ft	1.23

Percent Lighter by Weight	Stone Weight, lbs Minimum	Maximum
W100	185	463
W50	93	137
W15	29	69

========== Isbash Method
==========

Input Parameters:

Run Name: CHESTER3 Description: d/s channel

Average Channel Velocity, ft/sec	11.50
Unit Weight of Stone, lbs/cu ft	165.00
Turbulence Level	High

Output Results:

Computed D50, ft	1.69

*** Using Gradation from COE ETL 1110-2-120 ***

Computed D30, ft	1.38
Specific Weight, pcf	165.00
Layer Thickness, ft	3.00
Selected Minimum D30, ft	1.46
Selected Minimum D90, ft	2.12

Percent Lighter by Weight	Stone Weight, lbs Minimum	Maximum
W100	933	2,333
W50	467	690
W15	146	345

Rock d/s max.out

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PROGRAM OUTPUT

========== HEC-11 Method
==========

Input Parameters:

Run Name: CHESTER4 Description: d/s channel average conditions

Average Channel Velocity, ft/sec	11.50
Average Flow Depth, ft	5.00
Unit Weight of Stone, lbs/cu ft	165.00
Material Angle of Repose, ø	41.00
Cotangent of Sideslope	2.00
Safety Factor	1.10

Output Results:

Computed D50, ft 0.96

*** Using FHWA Gradation ***

Gradation Class Light
Layer Thickness, ft 2.92 (Increased by 50%)

Percent Smaller by Size	Rock Size, ft	Rock Size, lbs
D100	1.80	500
D50	1.30	200
D10	0.40	5

Bend Scour Estimation

Ref: Stephen T. Maynord, 1996
"Toe-Scour Estimation in Stabilized Bendways"
Journal of Hydraulic Engineering, August 1996, pg 460-464

Eqn 16

$$\frac{D_{mxb}}{D_{mnc}} = 1.8 - 0.051 * (R_c/W) + 0.0084 * (W/D_{mnc})$$

Where

D_{mxb} = maximum water depth in the bend
D_{mnc} = mean water depth (location not specified)
R_c = centerline radius of bend
W = water surface width
if: $(R_c/W) < 1.5$, let $(Rc/W) = 1.5$
$(W/D_{mnc}) < 20$, let $(W/Dmnc) = 20$

Event	Flow (cfs)	Dmxb * S.F.	Dmnc (Yh xs 611)	Rc	W (xs 4.8)	Rc/W	W/Dmnc	S.F.
Bank full channel								
10-cfs	10	1.95	0.32	45	12.55	3.59	39.2	1
50-cfs	41	1.81	0.69	45	14.29	3.15	20.7	1
60-cfs	48	2.10	0.8	45	34.77	1.29	43.5	1
Flood terrace								
75-cfs	60	2.04	0.9	60	35.15	1.71	39.1	1
2-yr	84	1.99	1.11	60	36.00	1.67	32.4	1
5-yr	125	1.95	1.33	60	36.88	1.63	27.7	1
10-yr	154	1.93	1.45	60	37.38	1.61	25.8	1
25-yr	208	1.91	1.7	60	38.34	1.56	22.6	1
50-yr	243	1.90	1.82	60	38.86	1.54	21.4	1
100-yr	280	1.89	1.97	60	39.44	1.52	20.0	1

Commentary:

Scour depths are 1.9 to 2.1-ft deep.
Pools are designed to be 1.5-ft deep and will be lined with 2.5-ft of immobile rock
Flood terraces will be lined with 2.5-ft of immobile rock.

Therefore:

Bend scour at pools is slightly deeper than designed.
Rock is designed to be immobile
Bend scour is accounted for in design.